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COLLECTING, ANALYZING AND INTERPRETING BIVARIATE DATA FROM
LEAKY BUCKETS: A PROJECT-BASED LEARNING UNIT

By

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A report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF MATHEMATICS

Approved:

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Abstract

Despite the significance and the emphasis placed on mathematics as a subject and field of study, achieving the right attitude to improve students' understanding and performance is still a challenge. Previous studies have shown that the problem cuts across nations around the world, both developing countries and developed alike. Teachers and educators of the subject have responsibilities to continuously develop innovative pedagogical approaches that will enhance students' interests and performance. Teaching approaches that emphasize real life applications of the subject have become imperative. It is believed that this will stimulate learners' interest in the subject as they will be able to connect theories with applications. In this study, a project-based learning approach developed for teaching in secondary schools is presented. The experimental approach will help students to formulate research questions, collect, record, analyze and interpret data. They will also be able to develop mathematical relationships and graphical representations for their data. An experimental unit has been designed to test this pedagogical approach.

Keywords: Project-based learning, Torricelli's equation, bivariate data, statistics

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Florence Obielodan

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1.0 Introduction

In this study, I have designed a learning unit for use in a secondary school Algebra 1 class. The goal is to teach students how to collect, record, summarize, display, analyze, and interpret real-life bivariate data using survey and experimentation methods. The academic skills incorporated into the unit include integration of literacy (reading, speaking, listening and writing), integration of technology (i.e., excel spread sheet, electronic calculator), collaboration and cooperative learning in groups, visual presentations, project-based assignments and scientific experimentation. The proposed learning unit is expected to equip the students with the ability to handle everyday challenges involving statistical applications. These may include, formulating investigative questions, comparing actual data with estimated predictions, and drawing conclusions from data and mathematical models.

The report begins with a narrative of my personal experience as a teacher; I then present different views about mathematics and pedagogy. Tracing related literature, I examine the effect of literacy in mathematics; cooperative learning and technology acquisition; and project-based instruction as a way to motivate students' appreciation for and learning of mathematics. Then a detailed explanation of my methods under the following subheadings: Scope and Sequence of Unit; Strategies for Differentiated Instruction; and Assessment and Evaluation; followed by the learning unit materials. I conclude with a brief summary of the writing and plans for future work which would include an implementation of the proposed learning unit in an educational school setting.

1.1 Background

Nigerian education, generally, is fashioned after the British equivalent. Accordingly, education in Nigeria is jointly administered by three levels of administration, that is, local, state, and federal governments. Primary (elementary) education is under the management of local governments, while state governments direct the affairs of secondary education. The set of one hundred two secondary schools with a spread over thirty six states and the federal capital territory, are referred to as unity schools. These schools are directly administered by the federal government, who's, main responsibilities comprise funding and supervising of federal tertiary institutions, including colleges of education, polytechnics, and universities.

The education structure is titled “the 6-3-3-4 system” (National Policy of Education, Handbook, 1989), thus, referring to six grades in primary schools starting students at the age of six years; secondary education with the lower three junior grades and the upper three senior grades; and an average baccalaureate degree in college lasting four years.

Mathematics is one of the core subjects in secondary schools and pivotal for admission into higher educational institutions. For close to three decades, government education policy has placed added emphasis on the sciences, including mathematics, compared to other school topics (National Policy on Education, 1989). Despite the emphasis on and the significance of science, comprehending the subject of mathematics is a major challenge to many students (Ale, 1981). Also, in regard to teachers, demystifying students' preconceived notions about the subject's difficult nature and leading them to comprehend mathematics is a major challenge (Ale, 1981; Ohuche, 1978). Consequently, Nigerian investigations are continuously addressing instructional approaches and techniques with special emphasis on student learning processes of mathematics.

Thus, researchers have attributed Nigerian students' low performance in mathematics to several factors which include learners' negative attitude (Tella, 1997), poor foundation, i.e. the quality of teaching received by learners from inexperienced teachers (Isa & Oche, n.d.; Salman, 2009), and method of instruction used by teachers (Isa & Oche, n.d.; Salman, 2009). The broad nature of the curriculum as well as too much emphasis on coverage of syllabi, rather than students' understanding of the course content, has made teaching and learning mathematics burdensome (Ale, 1981). Also, the learning environment in many learning institutions is not conducive. Thus, some state controlled schools, especially in rural areas, are ill equipped with basic facilities including furniture for students and teachers (Ale, 1981; Obielodan, 2009, unpublished manuscript). In addition, modern instructional facilities like computers, audio-visual aids, and internet access are, generally, not available in public Nigerian schools (Ale, 1981; Salman, 2009; Tella, 1997; Yusuf & Afolabi, 2010).

In my fifteen years of teaching in the Nigerian educational system, I employed traditional teacher-centered methods of imparting knowledge of mathematics with little modifications to real life situations. Most of the time, my colleagues and I devised instructional materials using items such as cardboard papers, and handmade charts, and we described scenarios that could support the students in appreciating and comprehending mathematical concepts and relationships. My pedagogical practices were basically reduced to techniques and methods (Giroux, 2004) rather than to critical and democratic practices (Giroux, 2004; Ladson-Billings, 1995).

As a teacher, my desire is to identify some causes of students' negative attitudes toward mathematics and, in turn, their low performance as well as to develop pedagogies and instructional methods for the engagement of students in meaningful mathematics. The National

Council of Teachers of Mathematics (NCTM, 2000) standards for school mathematics encourage mathematics educators to lead learners to become appreciative of mathematics by actively engaging in real mathematics. To effectively engage in meaningful mathematics, learners should possess creative abilities that afford them the opportunities to apply their mathematics skills to new situations beyond the classroom environment (Natsu, 2009). However, some individuals view mathematics as mystical or as a difficult subject (Cangelosi, 2003; Meece, Wigfield & Eccles, 1990; Wigfield & Meece, 1988). The authors of most mathematics textbooks also present mathematical topics as strings of disjointed algorithms, definitions, rules, and symbols that must be memorized thereby make it difficult for students to comprehend the subject matter. Contrary to these views above, this author believes that mathematics concerns a variety of concepts and their relationship. Apparently, if students must engage in meaningful learning, teachers have to modify their methods of instruction.

The purpose of mathematics education reform therefore, is to move instruction away from passive transmission and from rote memorization to a constructivist model, where the learner actively engages with other students and the teacher in inquiry, problem solving, and knowledge construction (Draper, 2002; Giroux, 2004; Ladson-Billings, 1995; Mistrestta, 2005). Mistrestta (2005) suggested that cognitive development in mathematics rests on instructional design which can be developed through continual training of teachers. As a result, Mistrestta suggested that periodic professional development programs will assist in improvement of educators' instructional methods regarding students' conceptual knowledge of mathematics. To this effect, National Mathematical Centre, Abuja, Nigeria in collaboration with the Nigerian Federal Ministry of Education, have been organizing a developmental program called "Train the

trainer”, at least once a year in each of the nation’s six geo-political zones to facilitate teachers’ pedagogical practices.

Hence, the experiences have led to the creation of a research-based learning unit that could lead students to engage in meaningful mathematics.

1.2 Theoretical Framework

During the fifteen years that I taught mathematics in Nigeria, I continuously attributed students’ poor performances and pessimistic attitudes to inadequate instruction due to limited technology. Yet, I discovered that students’ viewpoint toward mathematics is similar to those in other nation states including the United States (USA). Consequently, this author desires to identify possible causes of negative attitudes toward mathematics and to formulate pedagogies that meaningfully engage students. Regarding students’ involvement, researchers have attributed students’ low performance to lack of motivation (Tella, 2007); math anxiety (Hembree, 1990; Meece, Wigfield & Eccles, 1990; Wigfield & Meece 1988), method of teaching (Cangelosi 2003; Salman, 2009; Stevenson, Lee & Stigler, 1986), textbooks’ construction (Cangelosi 2003), and classroom environment that encourages or hinders students’ willingness or interest in learning (Bosse & Faulconer, 2008).

In one of his textbooks, Cangelosi (2003) enumerated four reasons for mathematics being viewed as mystical. These were,

- a. Failure to view mathematics from historical perspective.
- b. Failure to comprehend the discourse of mathematics.
- c. Fragmentation of mathematical topics into seemingly disconnected subtopics.
- d. Failure of students to construct concepts and discover relationship for themselves.

Furthermore, Usiskin (1991) viewed mathematics as a magnificent building with the topics of mathematics being its rooms interconnected in multiple ways. He explained that the mathematics building was extremely complex, and interrelated with other buildings devoted to social sciences, physical sciences, philosophy, business, and other areas of human activity. Some of the rooms had doors and windows with wide vistas to the real world, while others had little significance. The author noted that educators have the opportunity to select the doors to the rooms they want to open and the floors of the building upon which they want their students to spend their time. He believed it's important that educators select rooms with interesting features thereby motivating students to explore more on their own and engage them in meaningful learning.

Over the past couple of decades, alternatives to the traditional methods of teaching, featuring one blackboard, one outspoken teacher, and group of passive students (Draper, 2002; Giroux, 2004; Ladson-Billings, 1995) have emerged. They include, for example, (i) progressivism (Dewey, 1983), a pedagogical movement according to which students preferentially learn from real-world experiences and through social interaction; (ii) constructivism (Draper, 2002; Duffy & Cunningham, 1996), which involves learners constructing knowledge for themselves rather than acquiring erudition from 'authorities' like teachers and textbooks; (iii) inquiry-based learning – learning through discovery from investigations that require the use of human sensory organs-(Wilhelm, Walter & Sherrod, 2008; Morrison, McDuffie & Roth, 2009); (iv) cooperative learning, pedagogical practices that allow students to learn as they work together in small teams (House, 2007; Slavin, 1985,1995 and 1996; Slavin, Hurley, and Chamberlain, 2003); (v) collaboration (Esmonde, 2009; Kahveci & Imamoglu, 2007); (vi) group work learning through interactions in small groups (Esmonde, 2009; Kahveci & Imamoglu, 2007); and (vii) project-based learning (Atkins, 2009; Kohler,

Swank, Heafner and Powell, 2010; Wilhelm, et al., 2008). In spite of the various methods mentioned above, research has indicated that some mathematics educators felt constrained in adhering to the traditional teaching method of rote memorization (Slavin, 1985). Basically, these teachers' lecture centered on textbooks which present mathematical topics as sequences of disjointed algorithms, definitions, rules, and symbols, followed by several examples that students must memorize. Subsequently, the teacher assigns similar problems from the text book for students' in-class work and for homework which the class corrects during the next meeting. This method of instruction tends to increase students' algorithmic skills but inadequately develops their conceptual understanding of mathematics (Cangelosi, 2003).

Research has shown that the traditional method described above encourages competitive classrooms where very few students achieve learning goals and low performing students are completely alienated from the pedagogical process (Ladson-Billings, 1995; Slavin, 1985). Teachers, however, hold on to this method because it is "easy", instructors have become used to the method, or have become resistant to change (Draper, 2002; Morrison et al., 2009; Slavin, 1985). I used similar methods throughout my teaching yet felt the necessity to explore other research-based methods that could lead to meaningful mathematics for the students. The purpose of this study is to present a project-based learning unit for use in the teaching of a middle-school mathematics class. The design of the unit was based on suggestions from previous research (Kohler et al., 2010; Wilhelm, et al., 2008) and the method of instruction described in the unit is based on constructivist learning theory. Constructivists avowed that learners actively participate in learning by constructing conceptual knowledge and discovering relationships as well as by establishing connections between new information and previous knowledge (Cangelosi, 2003; Duffy & Cunningham, 1996; Echevarria, Vogt & Short, 2008, pp54-56).

2.0 Literature Review

2.1 *Literacy in Mathematics*

Most nations of the world provide their citizenries with basic education which include ability to read, write and perform basic arithmetic for easy governance. Literacy is more than mere ability to read and write as literacy also involves speaking, listening, and social interaction. Although Gee (2009) refrained from using the term literacy, he defined literacy as the ability to use language in reflecting about and acting on the world. In addition, many researchers believed that content-area reading and writing enhanced content area knowledge as well as reading and writing (Alvermann et al., 2004; Bosse, and Faulconer, 2008; Cervetti et al., 2005; Loranger, 1999; Meaney & Flett, 2006). In citing Swafford and Kallus (2002), Alvermann et al. defined content area literacy as “the ability to use reading, writing, speaking, listening, representing, viewing and other sign systems to construct meaning with print and nonprint texts”.

Bosse & Faulconer (2008) conducted a study on learning and assessing mathematics through reading and writing, and they asserted that “... reading and writing in mathematics curriculum are being grounded upon the understanding that students learn mathematics more effectively and more deeply when reading and writing is directed at learning mathematics.” The authors made clear distinction between ‘reading and writing about mathematics’ and ‘reading and writing in mathematics’ and implored mathematics educator to adopt the latter in their instruction. Reading and writing about mathematics develops students’ mathematical interest, while reading and writing in mathematics classrooms fosters learning in mathematics. In essence, exposing learners to the discourse of mathematics tends to lead them to convey meaningful mathematics and learn through their communication (Bosse & Faulconer, 2008; Gee, 1991; Jones, 2001; Pierce & Fontaine, 2009). Bosse and Faulconer suggested a model that

displays the significance of interplay among purpose (the goal of reading and writing), audience (readers of the text), climate (the classroom that encourages or hinders students' willingness to participate in learning activities), and context (the situation). The model was demonstrated with a group of teachers, and the authors concluded that students who have opportunities, encouragement, and support for purposeful reading and writing in mathematics classes will have a more concrete perception of concepts and be able to apply learning to alternate situations.

Furthermore, McIntosh & Draper (2001) suggested using learning logs in mathematics to aid students' comprehension of the subject. Learning logs are reflection journals (Elliott, 1996; McIntosh & Draper, 2001; Meaney & Flett, 2006) that give students opportunities to organize, analyze, evaluate, and refine their mathematical thoughts in writing, whereby students learn mathematics in the process of writing (Elliott, 1996; McIntosh & Draper, 2001). The authors found learning logs useful for students to make connection between new information and prior knowledge. In another study, Elliott (1996) found writing to be beneficial for both students and teachers. Accordingly, the benefits of writing included, writing to learn, evaluating conceptual understanding, correcting misunderstandings, summarizing lessons learned, and assisting teachers' determination of students' comprehension level and to modify instructions as may be necessary.

2.2 *Cooperative Learning in Mathematics, Science, and Technology Knowledge Acquisition*

Researchers have established that cooperative learning methods of instruction as well as the use of technology in teaching have aided students' learning of concepts (Gillies, 2007; Slavin, 1985). The definitions of cooperative learning and of cooperation vary based on the element of goal structures and the aspects of the tasks (Slavin, 1985). Slavin (1985) described

cooperative learning methods as structured, systematic instructional strategies that can be used at any grade level and in most school subjects. The structures of a cooperative learning strategy allow students to work together in small groups of between 2 and 5 members to accomplish shared goals during learning activities (Gillies, 2007). Also, according to most definitions of cooperative erudition, learners are individually accountable for their own and group members' learning as well as for their group's work (Slavin, 1985, 1995). Furthermore, Esmonde (2009) and Slavin (1995) recommended the cooperative learning strategy to promote equitable learning environments in knowledge acquisition (Esmonde, 2009) and for motivational development of learning (Slavin, 1995), respectively. In addition, Slavin (1985) affirmed that well structured and a sizeable number of learners in cooperative groups were essential for meaningful learning. He also believed that active participation of all members was vital for acquisition of learning. In some of his studies (Slavin, 1985, 1995), Slavin concluded that cooperative learning methods increased both the students' individual and the group members' accountability and motivation to learn.

In a recent study, House (2010), analyzing the effectual use of cooperative groups and technology in learning, reported on the effect of computer usage and cooperative learning instructional strategies on science achievements of students in the United States and Japan. In total, 12,633 students comprising of 4,540 from Japan and 8,093 from the United States took part in the study. The results showed a positive correlation between students' scores on science assessments and their use of computers for problem solving. Consequently, students who used computer application packages for problem solving scored higher on science assessments compared to students who refrained from computer usage. Interestingly, in this investigation, House (2010) found that the use of cooperative learning activities that involved learners working

in small groups on science projects correlated negatively with the students' science achievements. Thus, students, who earned higher scores on the science test, reported that they more frequently worked through science problems on their own. However, in an earlier work, House (2007) suggested that the use of cooperative learning in small groups of four students per group afforded students multiple opportunities to learn from the explanations of other students (House, 2007). The author also believed that combining lecture and cooperative learning is more productive for student learning than depending solely on cooperative learning as an instructional method (House, 2007).

In addition, researchers have indicated that incorporating technology into mathematics instruction has proved effective for knowledge acquisition. Appropriate use of technology can be effective for creating connections among multiple representations in mathematics (Garofalo et al., 2000). Also, Demski (2009) in a study concerning learning to speak math, used a web-based tutoring program, entitled "Math Help", to develop the mathematical skills of students who were English Language Learners. According to the author, most of the students who used the software were able to communicate their mathematical thinking both verbally and in written form within six months of use. Yet, Demski (2009) noted that the success of "Math Help" was due to the interaction between the instructor and the students rather than to the web-based program itself. Summarily, evidence have shown that combining cooperative learning strategy with the use of technology including but not limited to computer application packages will develop students' appreciation of mathematical topics and acquisition of knowledge.

2.3 *Project-based Learning*

Project-based learning (PBL) is a pedagogical framework that provides learners with collaborative opportunities to solve real world problems by posing and refining investigative inquiries. The students make interdisciplinary connections, collect, analyze, and represent data from instructor designed hands-on experiments, draw inferences, and communicate their ideas and findings to other participants (Kohler et al., 2010; Morrison et al., 2009; Natsu, 2010; Wilhelm, et al., 2008). Advocates of reform in mathematics and science education have called for the integration of math and science curricula as a means to strengthen students' understanding of and foster their appreciation for the interconnections between the subjects (Frykholm and Glasson, 2005; Herron-Thorpe, Olson and Davis, 2010; Morrison et al., 2009; Wilhelm et al., 2008; NCTM, 2000; National Research Council, 1996). The following paragraphs provide three examples of successfully implemented project-based learning achievements.

Wilhelm et al. (2008) described a project-based milieu in a middle-level integrated mathematics and science methods course. The study concerned 24 pre-service teachers and their effective exploitation of real-life contexts regarding Earth's moon in bridging mathematical and scientific understanding. The instructor of the pre-service teachers assigned a preliminary project work to explore "what causes the phases of the moon". Each day for a period of about 5 weeks, the pre-service teachers recorded daily observations about phases of the moon and drew sketches of the moon phases. After the preliminary stage, the instructor randomly assigned the students into three thematic groups named geometry, azimuth, and stargazers with 9, 7 and 8 members, respectively. Members of each thematic group further subdivided into two discrete groups, investigated questions directly related to their project work. The authors observed that

students conveyed difficulty applying basic mathematics, which included scaling, ratios and sine curves. As a result, the instructors used scaffolding activities, e.g. spatial geometrical modeling and sinusoidal curve lessons to activate background knowledge and project progress. The published results suggested that project-based learning environments allowed students to (a) engage in contextualized problem solving; (b) make connections within and across disciplines; (c) develop reasoning skills; and (d) accurately represent and communicate concepts both in written and verbal forms.

In a similar study, Morrison, Roth & McDuffie (2009) explored the effect of connecting science and mathematics using inquiry investigations to understand collection, analysis, and display of data. Morrison et al. worked with 46 pre-service elementary school teachers on individual inquiry investigation in their science methods course. The project design required each pre-service teacher to select a researchable topic from the following options: the moon, plant growth, invertebrates, or weather conditions. As an exercise of connecting science and mathematics, the students formulated research questions, articulated predictions, collected data, proposed explanations for their findings, and summarized their scientific learning experiences. In addition, they created graphical displays of their collected data and interpreted the graphs. Reform advocates posited that integrating mathematics and science curricula would facilitate the development of students' skills for collecting, analyzing, representing and interpreting real-world data from graphs and other forms of data representations (Morrison et al., 2009). Yet, the authors found that only few students maintained background knowledge of data collection, analysis and display.

The authors employed separate pre- and post-study questionnaires as well as pre- and post-study interviews of the participants to assess students' scientific and mathematical

knowledge of topics related to the data collections, analysis and representations. The pre-study questionnaire and interviews were conducted at the beginning of the semester while the post questionnaire and interviews were administered in the last week of the course. The results of the study allowed the authors to suggest that the pre-service teachers' understanding of data collection, analysis, and display improved due to scaffolding instruction used to facilitate their background knowledge. The increase in the pre-service teachers' understanding appeared linked to learners' own project data. However, the students may lack the abilities to transfer knowledge to other situations.

In a recent study, Herron-Thorpe, Olson and Davis (2010) applied engineering principles for creating models and toy cars in leading a group of middle school seventh-grade students' learning regarding scale, in a learning unit concerning enlargement and reduction of prototypes. The authors defined scale factor as "a ratio that describes the relationship between the measurement of full-sized objects and the smaller model" (Herron-Thorpe, et al., 2010). Thus the students explored the concept of calculating scale factors commonly used for designing toy models of real-life objects. The students measured the toys, and used the measurements along with the estimates of full-sized objects as ratios to calculate scale factors. Following a class discussion, the students created a term "little-to-big" for scale factor and developed algebraic equations " $b=sm$ " where 'b' represented the measurement of the larger full-sized objects, and 's' and 'm' denoted the scale factor and the measurement of the model, respectively. The students later discovered a relation for calculating scale factor as " $s=b/m$ ". The authors explained to the students that engineers use similar principles for experimental designs and new projects of buildings, vehicles, and other physical objects. For more than two days the middle school students explored the application of scales to proportionally contract and expand models of

objects. These models included scaling their own heights and parts of their body as ratios of their full body sizes. Additionally, the students studied fractions through that process. Subsequently, in a project-based learning milieu, students engineered models of objects using a variety of materials, e.g. foams as structural bricks, toothpicks, straw, and aluminum foil. In reflecting on the projects, the authors concluded that students learned to transfer knowledge from an illustrative toy model concept to the application of scale factors to others models and situations. In spite of the authors' claimed success with the reduction and enlarging unit, time was a limitation as some students needed more hours to finish their projects. The authors believed that students could have completed unfinished work at home; however, homework was beyond the students' school tradition. Another constraint mentioned by the researchers was the 'no use of calculator' policy enforced to assist students' development of algorithmic skills for computing long division. Nonetheless, the authors considered the learning objectives of contracting and enlarging objects achieved.

In summary, teaching strategies that provide students with opportunities to explore real-life situations through hands-on activities in cooperative groups and communicate their mathematical thoughts through reading and writing will deepen learners' understanding of the subject matter. The choice of content including relevant concepts, discoverable mathematical relationships, and appropriate applications is very essential in guiding students' learning. To effectively engage students in learning at the application level, the materials teachers use must be appropriate for diverse groups of learners and also useful for leading students to transfer knowledge to other areas of application. Hence, to realize these teaching goals, I have designed a unit of instruction for use in a secondary school Algebra 1 class.

3.0 Methods: Leaky Bucket Unit

The purpose of this work is to present a project-based learning unit for use in the teaching of middle school mathematics class. The unit, which I called Leaky Bucket experiment unit, is designed to teach students to collect, record, summarize, display, analyze, and interpret real-life bivariate data using survey, interviewing and experimentation methods. Students will learn how to incorporate statistical analysis into scientific reports by developing equations for predictions. I was inspired to create this unit by an interdisciplinary course that I took as a requirement for my masters program. The course called Applied Mathematics in Biology (AMB) was designed by Dr. Jim Hafner of Biology Department, and Dr. Jim Powell of Mathematics and Statistics Department at Utah State University. We met weekly for two hours of interactive lectures and three hours of laboratory sessions. It is expedient at this point to mention that I had no background knowledge of biology or applied mathematics. I credit my success in AMB to the course's structure, methods of instruction and hard work on my part. The professors used interactive methods to lead students to develop mathematical models useful for predicting ecological phenomena through collaborative and cooperative learning in groups of students. They probed students' understanding of concepts using higher order questioning strategies. AMB stretched me beyond my bounds but I learned a lot in the course through collaborative efforts and cooperative learning, and support from the instructors.

The unit I created is based on one of the laboratory sessions in AMB called Leaky Bucket. The unit is designed to include features of project-based learning. Students will assume the position of scientists and use data collected from experiments to formulate equations for out-flowing fluid from a reservoir with a predetermined initial fluid level. The equation will be used to predict emptying time and other flow parameters. Reforms in science education have

emphasized the importance of engaging learners in scientific practices, like developing, investigating and explaining scientific models (Schwarz et al, 2009). The authors suggested the need to involve learners in construction of models rather than working with models provided by teachers or scientific authorities. Students will read about Torricelli, an Italian physicist and mathematician who developed a model for predicting the emptying time of a leaky bucket. Learners would examine how their equations work compared to a renowned scientist like Torricelli.

The Leaky Bucket experiment unit is designed to last for eight days in middle school Algebra 1 class. This learning goal stated above, is defined by strings of daily content objectives with specified learning levels (Cangelosi, 2003) as well as language objectives (Echevarria, Vogt & Short, 2008) to aid textual comprehension. Cangelosi 2003 defined an objective's learning levels as "the manner in which students will mentally interact with the objective's mathematical content once the objective is achieved". I chose to design this unit for algebra 1 class partly because standard IV of Utah Core Curriculum for algebra 1, includes collecting, recording, analyzing and interpreting bivariate data using scatter plots and using best lines of fit to estimate predicting equations (Utah Secondary Mathematics Core Curriculum, 2007). The other reason was for my personal interest to learn more about Statistics.

3.1 Scope and Sequence of Unit

PBL promotes meaningful learning and prevent boredom which is commonly experienced by students in the traditional classroom (Natsu, 2009; Wilhelm et al., 2008). With PBL students are generally motivated to learn because learning activities are designed to include exploration of projects in their area of interest (Natsu, 2009). The unit I have created will engage

students in learning activities that allow them to write research questions that they will use for data collection, analyzing and interpretation. On the first day, students will watch video clips of two streets, a busy road and one with less traffic, they will be expected to decide which road the government should pay more attention to and why. The teacher will lead a class discussion that will explain the importance of data and statistics in real-life. Students will be introduced to some techniques of collecting data, the processes involved, and the challenges associated with data collection and representation on the second day. On the third day students will construct the knowledge of variables; they will categorize variables as dependent or independent, univariate, bivariate and multivariate. As earlier stated, the problem students are faced with in this unit is to determine the time it takes to empty any reservoir through an orifice on the side of the container. As a result, they will demonstrate with a jar of lemonade to determine how long it takes for everyone to get at least a cup of lemonade and the time it takes for the jar to empty completely. The students are expected to identify factors or variables that affect the emptying time. The lemonade experiment will be on the fourth day and on the fifth day students will be exposed to a real-life experiment. Similar procedures as the ones used by math biologists will be adopted for data collection. The learners will develop mathematical equations for predicting emptying time of leaky buckets based on collected data and interpret their results from scatter plots. These activities will take place on the sixth and seventh day. After presenting their data using manually created scatter plots, the students will use excel to display the same data and to make comparisons.

Algebra 1 students are already exposed to bivariate data with linear relationships (Utah Secondary Mathematics Core Curriculum, 2007). The Leaky Bucket experiment will afford them the opportunity to see bivariate data with nonlinear relationships which they will learn in

algebra 2. Constructivist learning theories assert that, learners acquire knowledge by connecting new information to past learning experiences (Dewey, 1983; Draper, 2002; Duffy & Cunningham, 1996). As such students will be able to compare and contrast real-life data with linear and nonlinear relationships.

Finally on the last day students will write a report to display all they have learned from the unit. The unit is designed, so that learners will mimic the same process researchers go through to get papers published. Students will be encouraged to write up their reports and post them on their classrooms bulletin boards if they chose to.

3.2 *Strategies for Differentiated Instruction*

Leaky Bucket unit is designed to accommodate the need of all students (English language learners, gifted child, and students with special needs). Techniques for making content concept clear and understandable include gestures and use of body language, modeling and demonstrating expectations, hand-on activities, use of multimedia and other technologies in lessons, adjusting and modulating speech (Echevarria, Vogt & Short, 2008) are incorporated into the unit.

Higher order thinking skills rarely dominate mathematics educators' teaching strategies (Stigler and Hiebert, 1999), making it difficult for students of mathematics to discover relationships between real world problems and mathematical tools available for suggested solutions to the challenge(s). The teacher's responsibility with PBL is to facilitate learning, but students are responsible for constructing knowledge of what they learn (Kohler et al., 2008; Morrison et al., 2009; Natsu, 2009; Wilhelm, et al., 2008). As such the teacher's responsibility with Leaky Bucket unit is to guide students to construct knowledge and discover relationships

for themselves (Cangelosi, 2003). The Leaky Bucket unit is planned to encourage cooperative learning and collaborative effort. Students with different achievement levels get to work together to learn and to help other members of their class to learn (Slavin, 1985, 1995).

3.3 *Assessment and Evaluation*

Garfield (1994) defines assessment as a dynamic process that continuously yields information about student's progress towards the achievement of learning goals and how such information is used to inform method of teacher's instructions. Assessments also evaluate how effectively lessons have been delivered (Echevarria, Vogt & Short, 2008). Effective assessment is beyond testing, grading and ranking students (Garfield, 1994). It is meant to evaluate teaching and learning (Cangelosi, 2003). Assessments are useful for monitoring students' progress (Jones, 2001) and for modification of instruction (Echevarria, Vogt & Short, 2008; Garfield (1994).

Daily homework assignments and a summary report of all that is learned are points of assessment included in the Leaky Bucket unit. Learners will receive feedback on the homework assignments which will give the teacher an idea of where individual student stands with regard to the learning goal for the purpose of modifying instruction accordingly. The final report will serve as a summative measure of student achievement of the unit goals.

4.0 Unit Materials

The Leaky Bucket learning unit with daily schedules is presented below. The materials required in each day include lesson plan, worksheet, homework assignment, and others. Reading extracts and power point slides are required in some of the days.

Overall learning goal:

The students will learn how to develop research question(s), and to collect, record, summarize, analyze, display and interpret real-life data in response to the investigative inquiries using scientific experiment. They will also learn to develop equations for making future predictions.

Overview:

Leaky Bucket experiment unit is designed to last for eight days in middle school Algebra 1 class. The goal is to teach students how to collect, record, summarize, display, analyze, and interpret real-life bivariate data using survey and experimentation methods. The students will learn different techniques of collecting, and presenting data with greater emphasis on scatter plot. They will also be taught the importance of statistics and data in real-life applications as well as how to incorporate statistical analysis into scientific reports.

The skills incorporated into the unit include integration of literacy (reading, speaking, listening and writing), integration of technology (excel spread sheet, calculator), collaboration and cooperative learning in groups, visual presentations, project-based assignment and scientific experimentation.

Subject/Class: Mathematics/Algebra1

Core Curriculum: Standard IV, objective 1 for days 1 to 5; objective 2 for days 6 to 8. (Utah State Core Curriculum)

Previous Knowledge: The background knowledge that students will need include fluency making linear measurements, finding averages, plotting data points on a Cartesian coordinate system, and determining slopes of lines.

Leaky Bucket Experiment Unit- Day 1

Content Objectives for Day 1:

The student should be able to

- I. Recognize the usefulness of statistics in everyday life. (Appreciation)
- II. Explain data and statistics in his or her own words. (Comprehension and Communication)
- III. Learn to collect and record data with at least two variables using method of interview. (Simple Knowledge)

Language Objective(s):

1. The student will explain the meaning and importance of statistics and data in his/her own words.
2. The student will display his/her understanding of statistics by responding to worksheet #1 and #2

Materials Needed:

1. Video clips of two streets or roads.
2. Worksheet #1 for each student.
3. Worksheet #2 for each group. Group members are expected to write the information needed to complete homework #1.
4. Homework #1 sheet for each student.

Sequence of Activities

- ❖ Introduce the unit plan, in a large class session by asking each student the month of their birth. Have one student come to the board and act as a scribe as each person calls out his/her birth month. Ask the class to respond to this question: In what way do you think the information on the board can help me as a teacher? Give them one minute to think about the question and call on students for their response. *Possible response may include, knowing and acknowledging their birthdays, may be you want to give us treats on our birthdays and need to know how many will be needed each month. May be you want to group students by the birth months, etc*

- ❖ The teacher leads a class discussion that will culminate in a working definition of data, statistics and their usefulness in everyday life.
 - Data can be define as information for the purpose of our unit study
 - Statistics can be defined as a process of collecting, analyzing, interpreting and presenting data, the result of which can be used for decision making and also for future predictions. [The teacher will be emphasized the importance of labeling in statistical analysis.]
- ❖ Have student watch video clip of two streets scenario, one is densely populated and the other is sparsely populated. Students are expected to count and record the number of vehicles travelling on both streets as seen on the video on the provided work sheet. Talk briefly on the video, discuss reasons why one street is busy and the other is not, and talk about the possibility of having different scenarios on the same street at different time of the day and respond to the questions on worksheet #1 later. *Possible discussion Question:* Suppose Utah Department of Transportation has a road project on its agenda. They want to expand one major road to a 4-lane highway. Which of the two roads viewed in this video clip, do you think should be top on their priority list and why? Why do you think, your choice may be incorrect? [By incorrect response, I intend for students to understand that it is possible for the scene in the video clip to be influenced by the time of the day during which the video was recorded, and that may not be the actual situation in everyday life.] *Expected response should include:* Time of the day the roads were recorded, if there are schools, worship center, work places, or a movie theater around the place that had just closed around that the time the video was recorded, the result can be incorrect.

traffic.mov (MOVIE)

- ❖ After the discussion, have student work independently on worksheet #1
- ❖ Have student break up into groups of 3 or 4. Each group will be given names such as Alpha, Beta, Phi, etc for the purpose of identification. Students will maintain the same group throughout the duration of the unit lessons. Each group would be

expected to choose a scribe to write their thoughts, propositions and to report to the class, the outcome of their group work or can call on any member of the group to present report if they so wished. The next activity will be in groups.

- ❖ Ask students to put away worksheet #1 and start working as a group on worksheet #2. The exercise will expose student to one technique of data collection called interview, presentation and interpretation. Data can be presented using tables, pictures, charts and graphs. Frequency distribution table is included in worksheet #2.
- ❖ Summarize the day's lesson and assign homework.
- ❖ Complete homework #1 before the next class. **Homework:** Go on the internet, check out statistics texts from the library and read about methods/techniques of collecting data in statistics. Write down some of the main ideas you discover from your reading and be ready to share with the class the next day.

Worksheet #1_ Statistics

Name: _____ Date: _____

Q1. How many vehicles did you see on road A? _____

Q2. How many vehicles did you see on road B? _____

Q3. Which road will you advice Utah department of transport division to work on? _____

Q4. Why?

Q5. Suppose you were told that your answer is incorrect, what are the possible reasons why you think there are more vehicles on one road than the other?

Worksheet #2_Survey

Name: _____ Date_____

Group Name: _____

Group Members:

Instruction/Directions for Q1: Each group scribe will ask members of his or her group to supply the following information about themselves. Record the responses in the blank spaces provided.

Q1:

1. In what month of the year were you born?
2. How old are you?
3. Your height in inches is -----
4. Number of people in your family is -----
5. Your favorite color is -----
6. Your shoe size is -----
7. The color of your eye is-----
8. What is your favorite subject?

Answer:

1. _____, _____, _____, _____,
and _____
2. _____, _____, _____, _____,
and _____
3. _____, _____, _____, _____,
and _____
4. _____, _____, _____, _____,
and _____
5. _____, _____, _____, _____,
and _____
6. _____, _____, _____, _____,
and _____

7. _____, _____, _____, _____,
and _____
8. _____, _____, _____, _____,
and _____

Q2. Re-write the information collected in Q1 in the table below

	Member1	Member2	Member3	Member4	Member5
Month of your birth					
Age					
Height in inches					
Number of people in family					
Favorite color					
Shoe size					
Eye color					
Favorite subject					

Q3. In what ways is the presentation of the responses to Q1 different from that of Q2? How are they related? Explain.

Q4. Which of the two forms of response presentations do you like the most and why?

Homework #1_ Data collection methods

Name: _____ Date: _____

Direction: Go on the internet and/or check out statistics texts from the library and read about methods/techniques of collecting data. Write down the main ideas from your reading and be ready to share with the class the next day.

Leaky Bucket Experiment Unit- Day 2

Content Objectives for Day 2:

- I. The student will be able to understand the techniques of collecting data with at least two variables. (Simple Knowledge/ Comprehension and Communication)
- II. The student will review previously learned skills of how to organize and present statistical data. For example, bar chart, histogram, circle graph, frequency table and line graph (Simple Knowledge)
- III. The student will present collected data from the previous day on charts and graphs (Algorithm Skill)
- IV. The student will decide what method is best for presenting certain information (Application)

Language Objective(s):

1. The student will explain how to present and interpret data and their choice of method of presentation.
2. The student will display his/her understanding of the different data collecting techniques by completing their guided note outline.

Materials Needed:

1. Smart board or Overhead projector.
2. Graph paper for plotting data
3. Ruler
4. Sample of old questionnaire
5. Picture showing interviewer and interviewee
6. Power point of data collecting techniques.
7. Homework #2 for individual student

Sequence of Activities

- ❖ Begin with the previous day homework. Call on some student to share what they learned from their engagement in the previous day homework.

- ❖ List and discuss methods/techniques of collecting data. Display the list using overhead projector.
 - Surveys
 - Interview
 - Questionnaire
 - Field works
 - Experiments
 - Observations

Methods of Data collection.pptx

- ❖ Teacher describes and dramatizes each of the techniques with students; explains how researchers use these methods. S/he displays and passes around samples of questionnaire and show pictures of scientists at work using some of the methods. Note: teacher can use power point presentation to illustrate techniques, incorporate pictures and video of researchers at work to aid students' comprehension of the concept.
- ❖ Teacher provides students with outlines/guided note for writing summary of main idea about the techniques presented in class. He/she will provide one-on-one assistance/instruction if necessary, for low and average achievers, as well as English learners.

The teacher concludes this section by explaining to students that we will explore the use of data collection by experiments in detail in the course of our study. The goal is to use mathematical relationships for predicting the emptying time of Leaky Buckets (buckets with draining hole(s)), given initial water levels.

- ❖ Teacher then moves on to discuss the usefulness of data presentation in statistics. Review presentation methods by plotting data collected by the different groups in the last class.
- ❖ Students will plot one item from their group's data collected in the previous class using any method of their choice. Take note of the method of presentation, have them explain their choice of method; discuss data labeling (with emphasis on the importance of

labeling in statistical data). *[For consistency, teacher can chose a particular method of presentation and have all students work on the same method. The teacher will lead students by plotting the first few points and have students volunteer to plot the remaining points]*

- ❖ Students work independently on worksheet #3, while the teacher walks around to assist them and offer suggestions. Struggling students can be allowed to work with peers, that is, use peer tutors and or through cooperative learning groups.
- ❖ Discuss worksheet #3 and clarify misconceptions, worksheet is graded in class by students.
- ❖ Review of the day's activities and lesson objectives. Conclude by assigning homework.

❖ **Assign Homework #2:**

Select one item from the list of the information collected by your group (age, month, shoe size, color of eye, etc) and represent this information using box-and-whisker plot.

Guided Note: Summary of data collection methods**Interview:****Questionnaire:****Survey:****Observation:****Field work:****Experimentation:**

Worksheet #3_ Data representations

Name: _____ Date: _____

Direction: Read the information below and answer the questions that follow

Mrs. Cannon wants to study the distribution of the scores for a 100-point unit exam given in her first-hour mathematics class. The scores of the 25 students in the class are listed below.

82 77 49 84 44

98 93 71 76 65

89 95 78 69 89

64 88 54 96 87

92 80 89 85 93

- a. Make a stem-and-leaf plot for the mathematics exam scores. [you can find steam-and-leaf on page -- of your mathematics textbook]

--	--

- b. Represent the information on a frequency table with the intervals 40-49, 50-59, 60-69, etc (You can find frequency table on page -- of your mathematics textbook)

Test interval	Number of student
40-49	
50-59	
60-69	
70-79	
80-89	
90-99	

- b. Construct a histogram for the exam scores. [you can find histogram on page -- of your mathematics textbook]

c. What is the highest score on the exam? _____

d. What is the lowest score? _____

e. Which test score appear most frequently? _____

Homework #2_ Presentation of data

Name: _____

Date: _____

Select one item from the list of the information collected by your group (age, month, shoe size, color of eye, etc) and represent this information using box-and-whisker plot.

Leaky Bucket Experiment Unit- Day 3

Content Objectives for Day 3:

- I. The student will distinguish between examples and non-examples of variables.
(Construct a Concept)
- II. The student will develop a working definition of variables. (Comprehension and Communication)
- III. The student will identify examples and non-examples of dependent and independent variables. (Simple Knowledge)
- IV. The student will identify examples of univariates, bivariates and multivariates.
(Simple Knowledge)

Language Objective(s):

1. The student will define variables using a student-friendly language

Materials Needed:

1. Worksheet with pre-grouped list of examples and non-examples of variables for each group.
2. List of variables to be sorted.
3. Frayer model for each student.
4. Mini –Experiment #1 worksheet for each student.
5. Homework #3 for each student.

Sequence of Activities

- ❖ Start the day with mini experiment #1 (a quick formative assessment, useful for evaluation of teaching and learning)
- ❖ Students break up into their groups of 3 or 4 and work on the worksheet #4, part 1. They are to construct the concept of variable, identify characteristics of variable; differentiate between groups of examples and non-examples.
- ❖ Groups share their work with the whole class.
- ❖ Teacher clarifies misconceptions if any and leads the class to agree on a class definition of variable.
- ❖ Student writes summary of the discussion on variables using Fryer model.

- ❖ Teacher explains types of variables within the context of our unit. Independent and dependent variables, univariates, bivariates, and multivariates.
 - **Dependent Variable:** These are variables whose values are directly dependent upon the values of other variables in mathematical relations. For example: The growth of a plant is directly dependent upon water, sunlight and soil nutrients. *Growth is the dependent variable, water, sunlight and soil nutrients are the independent variable.* The age and height of children. *Height is dependent on age. Age is independent and height is dependent.* **Note:** dependent and independent variable can only be determined in cases with more than one variable.
 - **Independent Variable:** These are variables whose values determine the value of the dependent variable. They are variables that researcher can change to determine their effects on dependent variables. For example, age, water, sunlight and soil nutrients are the independent variables in the example above.
 - **Univariate:** is a set of data that consist of single variable type. For example: the ages of students in algebra 1 and geometry class. The variable is Age. Univariate: uni means one, and variate is from variable.
 - **Bivariate:** is a set of data with two variables. Example: Time taken to study for a test and test scores. Bivariate is a composite word, Bi means 2 and variate is from variable.
 - **Multivariate:** is a set of data that consist of more than two variables. Multi is a short form of multiple. *Refer to the example used for dependent variable.*
- ❖ Give students 5 minutes to brainstorm in their groups and come up with more examples of variable types, then call on groups to share with the class.
- ❖ Have students work independently on part 2 of worksheet #4.
- ❖ Grading of part 2 of worksheet #4: call on students to share their answers and make necessary corrections if any.
- ❖ Assign homework #3

Guided Notes:

Bivariate
Multivariate
Univariate
Dependent variable
Independent variable

Mini- experiment #1

Name_____ Date_____ Class_____

Prompt

List and explain three techniques or methods of collecting data.

Response:

1.-----

2.-----

3.-----

Total point obtainable: 9***Rubric***

- +1 for each correct method
- +0 for each incorrect method
- +2 each, for explanations that include main idea of listed method and without any erroneous response
- + 1 each, for not so clear response
- +0 each, for response that appear erroneous

Fraye Model

DEFINITION	CHARACTERISTICS
EXAMPLES/MODELS	NON-EXAMPLES

Sample of filled in Frayer Model

DEFINITION	CHARACTERISTICS
<p>A symbol or letter which represents a changing quantity or quality</p> <p>Variables: are quantities represented by symbols whose value or worth changes. For example X and Y, are variables in the expression $X + Y$. Both can assume any value.</p>	<ul style="list-style-type: none"> • Varies/changing • Is measureable • Can be quantities or quality • Quality e.g. good or poor/bad, yes or no, etc • Not a constant
EXAMPLES/MODELS	NON-EXAMPLES
<p>The value of $X + Y$</p> <p>The value of $X + 2$</p> <p>The value of X, when X is greater or equal to 5</p> <p>The speed at which a candle stick burns</p> <p>Number of vehicles arriving a bus stop daily</p> <p>Time spent studying for a test</p> <p>The noise level in a class when the teacher leaves the room</p> <p>Effect of fertilizer on plants</p> <p>Favorite music of teenagers and their parents</p>	<p>X=5</p> <p>The value of X in, $X + 2=5$</p> <p>Number of vehicle that arrive a bus stop at exactly 2 :30 P.M on Monday, July 19 2010 afternoon.</p> <p>Effect of fertilizer on the class project plant.</p> <p>The student who sits in the center of the class.</p>

Worksheet #4_Variable Example Sheet

Name_____ Date_____ Class_____

Part 1**Examples:***(Students' worksheet will exclude the title variables just group of examples and non-examples)*

- ✚ The level of noise in a class when the teacher leaves the room.
- ✚ Length of time taken to study in preparation for end of unit test.
- ✚ Favorite class of music of teenagers or their parents.
- ✚ The speed at which a candle stick burns
- ✚ Number of vehicles arriving at a bus stop daily.
- ✚ Effect of fertilizer on plants
- ✚ The value of X, when X is greater or equal to 5
- ✚ The value of $X + Y$
- ✚ The value of $X + 2$

Non Example:

- The number of vehicles that arrive at a bus stop at exactly 2:30pm on Monday July 19, 2010 afternoon.
- The value of Y, when $X + Y = 25$; given that $X = 10$ (Note: X and Y are positive integers)
- $X + 2 = 5$, if X is an integer, its value is
- The student who sits directly behind Jon Jones in our Science class.

Question

Examine the group of examples and non-examples and write three things that make the group of examples different from the non-example group.

Response

1. -----
2. -----
3. -----

Part 2

Direction:

A Identify which data set or statements are univariate and which are bivariate and name the variable in the statement.

1. The number of goals scored by the school basketball team
2. The number of people in a household and their family income.
3. The sizes of sneakers and their prices.
4. The amount of gas in a car and miles travelled.
5. Number of hours spent studying for geography and science test.
6. The month you were born and the first letter of your name.
7. Effect of fertilizer on plants.
8. Favorite music of teenagers and their parents.

Univariate	The variable	Bivariate	The variables
Example #1	# of goals	#2	# of people & income

B Classify the following as dependent and independent variable.

1. The number of hours spent studying for a test and the test score.
2. The age and the height of babies.
3. The level noise in the classroom and teacher's presence.
4. Time spent in the mall and dollars spent in the mall.
5. Distance travelled by a car and the amount of gas in the car.

Statement #	Independent	Dependent
1		
2		
3		
4		
5		

Homework #3_ Volume problem

Name: _____ Date: _____

Direction: Explain the process that you will use to solve the following problem (You do not need to solve the problem just explain the steps involved).

Question: Suppose the diameter of a Soda can is d cm and a height of h cm, find the volume of the soda in the can if 0.5 cm of space is left at the top of the can to allow for expansion?

1. What information gives you the clue on how to solve the problem?

2. Identify the key variables and their values in the problem.

3. Write an equation to show how you would solve it?

Leaky Bucket Experiment Unit- Day 4

Content Objectives for Day 4:

- I The students will decide what variables are important for determining how long it takes to drain water from a container. (Discover Relationship)
- II The students will decide what method to use to collect the data needed to predict emptying time of water through an opening by the side of a container (or leaky bucket). (Discover Relationship)
- III The student will learn how to collect and record bivariate data from experiment. (Simple Knowledge)

Language Objectives:

- 1. The student will explain the process involved for draining water out of a container through a hole.
- 2. The student will explain what the collected data mean.

Materials Needed:

- 1 Mini –Experiment #2 worksheet.
- 2 Jar of lemonade with faucet
- 3 Serving cups
- 4 Video of scientists collecting data (Optional)
- 5 1- 2 liters plastic jugs
- 6 Stop watch
- 7 Tape
- 8 Graduated cylinder for measuring volume
- 9 Large plastic dish for draining water
- 10 Stands and plates for elevating the buckets
- 11 Data sheet for recording
- 12 Calculator

Sequence of Activities

- ❖ Begin the day's lesson with mini experiment #2, to be graded in class. Have students correct their work if necessary. You may need to review previous lesson if necessary, depending on mini experiment evaluation result.
- ❖ Instruct students to discuss homework #3 in their groups and attempt to resolve any differences in their answer.

Sharing Lemonade in class

- ❖ The class will experiment with how long it takes to empty a jar of lemonade. Each student will be given a cup.
 - Before sharing, have students make predictions in their groups on how many minutes it will take to serve everyone in the class. If our goal is to empty the lemonade jar how many minutes will it take.
 - Talk about how long it will take if serving is continuous versus if we have to serve one cup turn off the faucet, and then serve the next person until the last person is served.
 - Have students discuss what factors (variables) will affect the emptying time.

Go on the serve the Lemonade

- Lead groups to observe what happen to pressure of the flow when the bucket is full versus when it is almost empty. *Observe how long it takes to empty a full bucket versus half-full bucket.*
- Take note of what happens with the flow if the faucet is turned on fully and when it is somewhere half-way. Let student know how flow rate compares with the size of the hole on the bucket. Ask students to note the effect of the water level and the size of the hole to how long it takes to completely empty a bucket.

- After the drink is completely emptied, ask groups to compare the actual time readings with their predictions and make conjectures about why their predictions were correct or incorrect.
- ❖ Call on groups to share what they discussed in their groups and attempt to resolve any differences in their answers.
- ❖ Talk briefly about what scientist do in experiments as a class. Review experimental method of collecting data. Review the unit goal with the student: students need to use **mathematicians'/scientists'** equation to predict the height and emptying time of any leaky bucket.
- ❖ Ask students what factors will affect how long it takes for a bucket to empty if we can control or chose the size of the hole. *Possible response is the level of water in the bucket.* Explain to the student that emptying time will dependent on the height of water in the bucket. So that **height** is *independent* variable and **time** is *dependent* variable, the situation can also be reversed so that we predict the height of water at a particular time, which makes *time independent and height dependent variables* respectively.
- ❖ Explain specifically that the equation we are about to determine will give us height at a particular time. What this mean is that a change in height will affect the time and vice versa. As height of water decreases in the bucket time will increase.
- ❖ Talk about what pattern is made by plotting each ordered pair of height and time on a Cartesian plane. For example, given (h_1, t_1) ; (h_2, t_2) ; (h_3, t_3) , etc. we could have a linear or nonlinear graph. Review slope with students, tell them our homework today is a review of slope.

Introduce Leaky Bucket Experiment

- ❖ Watch video of Leaky bucket experiment(Optional)
- ❖ Give real-life examples of Leaky Buckets applications. For example need to wash and change water in a fish tank or aquarium along side with other assignment.
- ❖ Leaky Bucket experimental set up:

Introduction

Students will use data from this experiment to formulate a model for out-flowing fluid from a reservoir with a predetermined initial fluid level. The model will be used to predict emptying time and other flow parameters. They will present data using scatter plots, and establish correlation between the volume of water and the emptying time. Students will identify the relation if any as linear or nonlinear having either negative, positive or zero correlation. Torricelli developed a scientific model/equation for predicting emptying time of fluid through an orifice. We will be determining how our proposed equations compare with Torricelli's.

Students will be supplied with buckets (empty gallons of milk, 2-liters soda bottles, juices containers, etc) which have holes already made at the lower sides of the bucket through which water can flow out. (This is necessary for safety purposes to prevent students from been hurt in the process of handling drill or scalpels for cutting holes). They will calibrate their buckets in centimeters in order to read water heights at any time during the experiment. The dimensions of the buckets will be measured for the purpose of calculating their cross-sectional areas and also to calculate the surface areas of the holes.

At the start of the experiment, the holes will be sealed up and water poured to predetermined height in the bucket. Responsibilities will be shared in each group during the experiment. In each of the groups, a group member will be required to use a stop watch to record time at intervals of 1cm drop in water level. Another member will read water level while the third person writes the time taken and corresponding water level. This will be carried out until the bucket is emptied. The experiment will be repeated three times.

- ❖ Give groups 5mins to brainstorm on how they want to get the information needed to determine the equation. Tell them they will be provided with buckets that have draining holes in them and they could ask for any other supplies they want. Let them decide the type of buckets, shape and size of hole they will like to work with and how they plan to record their data. Students will be expected to share responsibilities within their groups at this stage.
- ❖ Let groups share their plans and method with the class and take time to revise their plan if necessary. Groups should make a list of materials needed for the collection of data the

next day, and submit their list to the teacher so that the materials can be made available before class.

- ❖ Have students chose a bucket type and work on calibrating their bucket, and measure the dimensions on their buckets, calculate cross-sectional areas of buckets and holes. Write out direction clearly on the board or on the overhead projector.
- ❖ Make closing remarks and assign homework #4.

Direction for calculating cross-sectional areas and areas of Holes

Bucket types include half-gallon milk jug, one-gallon milk jug, 2-liter soda bottle, etc. There two methods for measuring the dimensions. Teacher can demonstrate how to take measurements of buckets' dimension for the whole class to observe and do same in their groups.

Method 1

- ✚ first make a free hand sketch of the base of the bucket
- ✚ measure all the sides
- ✚ calculate the cross-sectional areas using the dimensions
- ✚ calculate areas of holes

For example

Bucket type: half-gallon milk jug

Sketch



Dimension: diameter = 4cm

$$\begin{aligned}\text{Cross-sectional area, } A &= \pi r^2 \times 1 \text{ unit of height} = 3.14 \times (2^2) \\ &= 12.56 \text{ cubic cm}\end{aligned}$$

Method 2

Find the volume of 1 unit of water by pouring the water into a graduated cylinder.

For example the difference in the volume of water at height 10cm and height 9cm is the same as the cross-section area of the container.

Mini- experiment #2

Name_____ Date_____ Class_____

Prompt

1. Variables are _____ quantities, and not _____
2. The statement “The ages and the first letter of students’ names” is an example of _____ type of variable.
3. How is dependent variable different from independent variable?

4. Identify two characteristics of variables
 - (i)
 - (ii)

Total point obtainable: 7***Rubric***

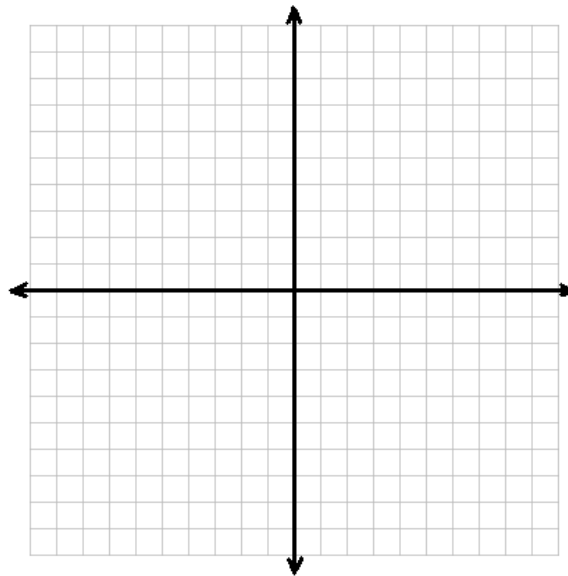
- +1 or + 0 for each of the blanks in question1 and 2
- +2 for explanations that include difference between dependent and independent variables without any erroneous response
- + 1 each, if differences are not clearly stated
- +0 each, for response that appear erroneous
- +1 for each correct characteristic
- +0 for each incorrect characteristic

Homework #4_ Cartesian coordinates and Slope Review

Name: _____ Date: _____

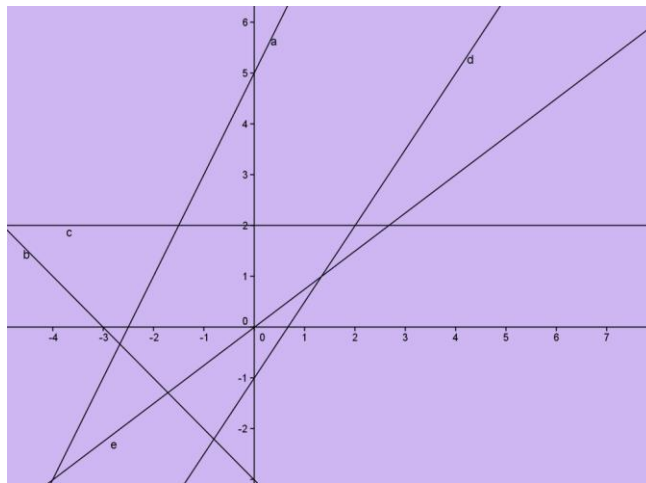
Remember all points are named as (x, y) and called ordered pairs. The x-axis is the horizontal axis (the run) and the y-axis is the vertical axis (the rise).

1. Doris sits on a seat which is on the third row and on the fourth column, while Greg's seat is on the fourth row but third column. Are both students sharing the same seat? Yes/No. Explain the reason for your answer, use diagram if possible.
2. Plot and label the points A $(-5, 5)$; B $(-8, -3)$; C $(5, -3)$ and D $(8, 5)$ on the graph below. Join your points using straight lines, what shape have you drawn?



3. Recall that the slope of a line is defined as rise over run or change in y over change in x . write a formula for finding the slope of the line containing the points (x_1, y_1) and (x_2, y_2) .

4. The line with the equation $y = mx + b$ is a straight line with slope _____ and y-intercept _____.
5. Find the slope of the line containing the points $(-2, -3)$ and $(5, -3)$
6. Find the slope of the line that passes through the points $(0, 0)$ and $(4, 3)$
7. Classify the following lines as having positive, negative, zero or undefined slope. Write your answer on the line below the graph.



- a. -----
- b. -----
- c. -----
- d. -----
- e. -----

Leaky Bucket Experiment Unit- Day 5

Content Objectives for Day 5:

- I The student will review previously learned skills of plotting points. (Algorithmic Skill)
- II The student will review how to find the slope of a line given the graph of that line. (Algorithmic Skill)
- III The student will collect and record bivariate data from experiment. (Algorithmic Skill)
- IV The student will graph bivariate data on a scatter plot and interpret results (Algorithmic Skill and Comprehension and Communication)

Language Objective(s):

- 1. The student will explain and summarize the procedure for finding slope of a line.
- 2. The student will explain the result obtained from the scatter plot.

Materials Needed:

- 13 1-4 quart plastic jugs, such as those containing milk or juice for use as the leaky buckets with pre-drilled/cut holes of different shape and size
- 14 Rulers
- 15 Stop watches
- 16 Tape
- 17 Graduated cylinders for volume measurement
- 18 Plastic dish washing tubs for water and/or large sink for draining water
- 19 Flowing tap or water
- 20 Ring stands and plates for elevating the buckets
- 21 Data sheet for recording sample from experiment
- 22 Calculator
- 23 Graph paper
- 24 Homework #5

Pre-class arrangement or Lesson Preparation

Before class, set up the necessary materials for each group, the list will include those listed above and specific group requirements as submitted the previous day.

Sequence of Activities

- ❖ Begin the day's lesson by instructing students to discuss homework #4 in their groups and attempt to resolve any differences in their answer.
- ❖ Review how to plot points and slope of lines with the class using following examples. Determine the slope of the line containing the points with the coordinates listed in the table below

x	-6	-3	0	3	6	9
y	8	4	0	-4	-8	-12

- To plot the coordinates on the Cartesian plane is to draw two lines, a horizontal line, which is the x-axis and a vertical line, which is the y-axis. Both lines intersect at the origin, the point (0, 0). Then move along the x-axis the specified number of places and on the y-axis. For example the first ordered pair is (-6, 8), will be -6 along the horizontal and 8 on the vertical the point where the lines meet will be marked and labeled as (-6,8) in the plane. **Note: take time to explain that (3,4) is not the same as (4,3)**
- Plot the first two points; give students time to plot the remaining points on their graph paper. Then have students volunteer to come to the board to plot the remaining points. After which the points can be connected/joined by a straight line. Move on to talk about slopes.
- Recall the definition of slope. The slope m of a line is change in y over change in x , simply rise over run $m = \frac{\text{change in } y}{\text{change in } x}$ or $m = \frac{\text{rise}}{\text{run}}$
- Explain slope in terms of difference between the terms, for example, $x: -3 - (-6) = 3$; $0 - (-3) = 3$; etc and on for $y: 4 - 8 = -4$; $0 - 4 = -4$; etc

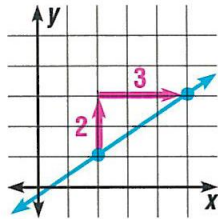
So the slope will be

$$m = \frac{\text{change in } y}{\text{change in } x}$$

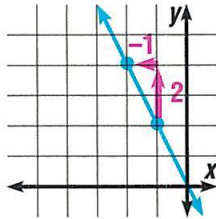
$$= \frac{3}{-4} = -\frac{3}{4}$$

- Discuss the different types of slope as follows

Determine the slope of each line.

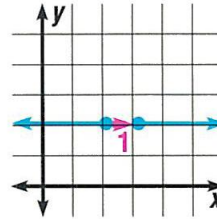


$$\frac{\text{change in } y}{\text{change in } x} = \frac{2}{3}$$



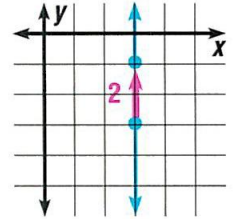
$$\frac{\text{change in } y}{\text{change in } x} = \frac{2}{-1}$$

$$= -2$$



$$\frac{\text{change in } y}{\text{change in } x} = \frac{0}{1}$$

$$= 0$$



$$\frac{\text{change in } y}{\text{change in } x} = \frac{2}{0}$$

The slope is undefined.

Copied from textbook

Let students cross check their homework with other group members' work and the class discussion. Have them make corrections if any. Tell students that understanding how to plot points and how to determine the slope of lines will be useful for the Leaky Bucket experiment.

Collection of Data

- ❖ Go on to data collection from Leaky Buckets. Have student discuss/review in their groups how they want to collect and record data from leaky buckets.
- ❖ Responsibilities will be shared within each group, assign a group leader, he/she will report for their group. One group member will use a stop watch to record time at intervals of 1cm drop in water level or height. Another member will read water level while the third person writes the time taken and corresponding water level. Have groups gather materials so that groups can start data collection.
- ❖ During data collection,
 - Groups will seal up the hole on their bucket with a duct tape.
 - Fill their bucket with water to a desired height.

- The group leader gives the start signal; one person removes the duct tape at start and call out the marks at 1cm interval. For example, if the desired height is 10cm, the caller will call 9, 8, 7, ...
- One member will use the stop watch to read the time in seconds at a corresponding interval. For example, 3sec, 7, 11, ...
- The recorder will write both height and corresponding time, on the data sheet e.g. (10, 0), (9, 3)...
- The experiment will be repeated three times for each bucket, (three trials per bucket type).
- ❖ Have groups switch buckets and switch responsibilities within groups, to collect more data. They can also experiment with how long it takes to fill their bucket. ***Make suggestions but let students be creative and experiment with their own methods.***
- ❖ Have groups experiment with filling their buckets at a particular flow rate to establish a linear relationship since the draining is not likely to be linear.

Analyzing data

- ❖ After collecting data, have student put away their data collection sheet and clean up.
- ❖ Ask students to brainstorm on how to find the average of trials per experiment. Review averages with the class using this example.
 - Question: Find the average of the first five positive integers.
 - Solution steps
 - List out the integers as follows 1, 2, 3, 4, 5
 - How average calculated or what is the formula for calculating average?
The mean or average of a set of data is sum of numbers or items in the set divided by the number of numbers or items in the set. i.e. *Average* = $\frac{\text{sum}}{n}$
 - $\text{Sum} = 1+2+3+4+5 = 15; n=5$
 - $\text{Average} = 15/5=3$

- ❖ For the group data, calculate average for each height point. Each student in the groups should take two or three height points and calculate the average time of all three trials. Have them record average time in the space provided. Each group leader or whoever is assigned as the group scribe, should write out the summary of their group data in the summary section under the caption height and time, where time is the average of all three replications.
- ❖ Have each student copy summary of his/her group's experiment. They will need it to complete homework #5

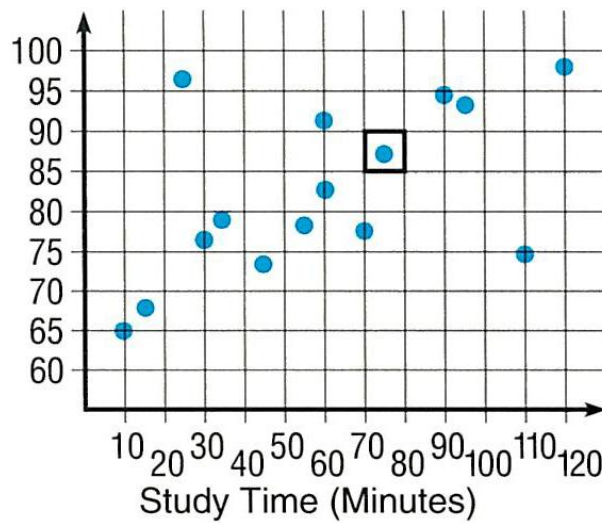
Scatter Plot

- ❖ Now that students have their groups' data, ask questions about the data. "What is happening to time as height increases or decreases?" what do you noticed with the change, will you rather say the change is constant or not? Why?
- ❖ Let student know that it is possible to see a pattern and observe how two variables are related from tables, but it is easier to visually observe a relationship from graphs and pictures.
- ❖ Introduce scatter plot as a way to visually observe the relationship between two variables. Use the following data set as an example. Plot the first few points; give students 3mins to plot the remaining points on their graph paper. Then have students volunteer to come to the board to plot the remaining points. Label the axes and remind students to always label their work. Discuss the relationship between the variable- study times and test scores- as presented by the scatter plot.
- ❖ Review lesson, check mark the learning objectives for the day.
- ❖ Assign homework #5.

Homework: each student should make a scatter plot of their groups' leaky bucket data. **Everyone is expected to have height on the x-axis and time on the y-axis,** for ease of comparison.

Student	Study Time (min)	Test Score (out of 100)
Justin	60	92
Penny	55	79
Doug	10	65
Brad	75	87
Carmen	120	98
Yoshica	90	95
Greg	110	75
Allison	45	73
Montega	30	97
Shelley	95	94
Emilio	60	83
Cecilia	15	68
Latoya	35	79
Ben	70	78
Hanna	25	97

Test Score



Copied from textbook

Homework #5_ Leaky bucket Scatter Plot

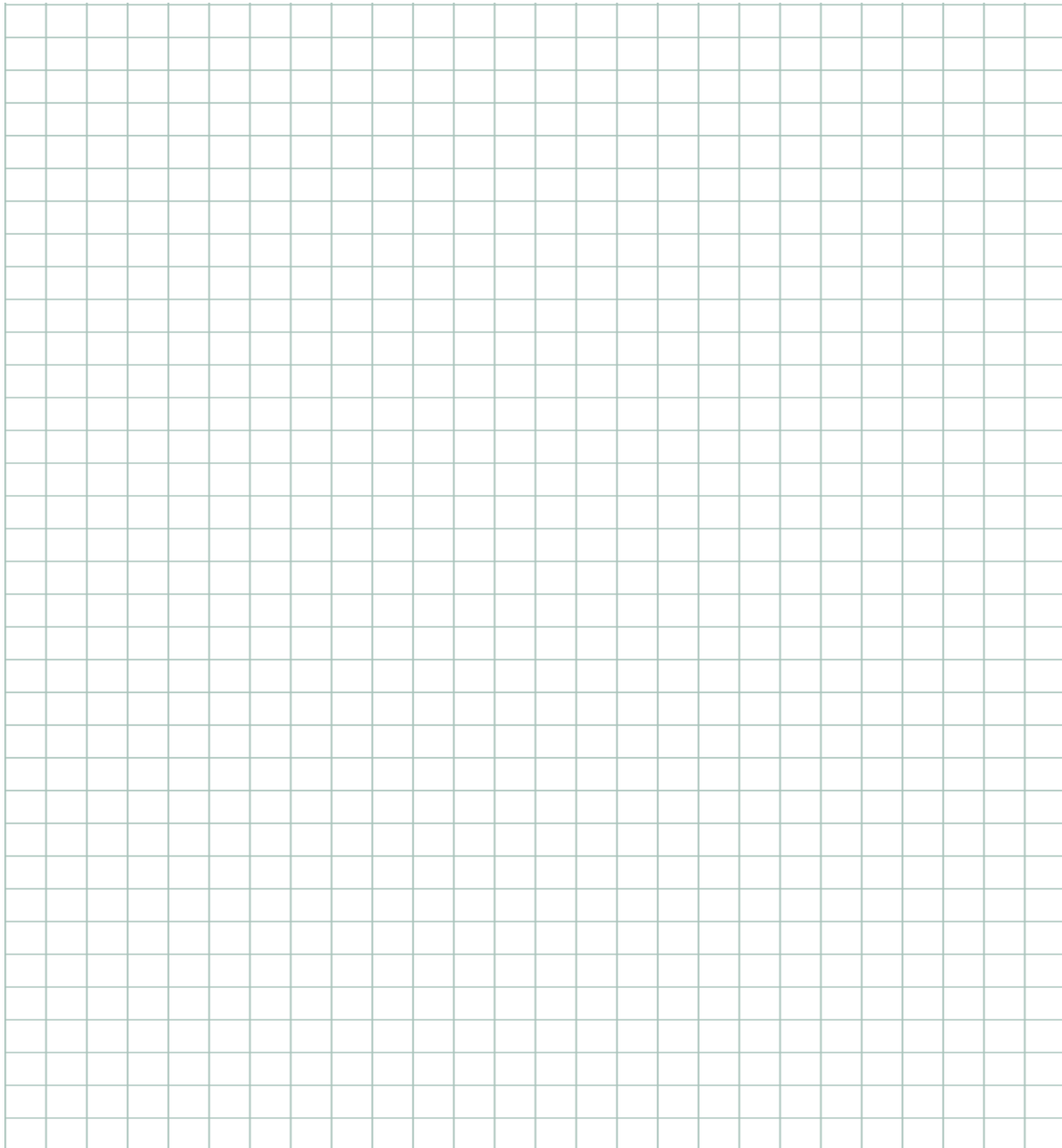
Name: _____

Date: _____

Group members _____

Direction: Make a scatter plot of the data that your group collected. Be sure to label your axes.

You are expected to Plot height on the x-axis and time on the y-axis.



Data collection sheet

Group name _____ Date _____

Group members _____

Bucket type _____ Cross-sectional area _____

Shape of hole _____ Area of hole _____

[illegible]

Group name _____ Date _____

Group members _____

Bucket type _____ Cross-sectional area _____

Shape of hole _____ Area of hole _____

Height (cm)	Time (seconds)			Average		Summary	
	Trial 1	Trial 2	Trial 3			Height	Time

Leaky Bucket Experiment Unit- Day 6

Content Objectives for Day 6:

- I. The student will learn to make scatter plot of real data that he or she collected. (Algorithmic Skill)
- II. The student will distinguish between examples and non-examples of variables with approximately linear relationship. (Construct a Concept)
- III. The student will classify bivariate relationship as linear or nonlinear (Comprehension and Communication)
- IV. The student will classify bivariate linear relationship as having positive, negative or zero correlation. (Comprehension and Communication)
- V. The student will draw and estimate the equation of best line of fit for the scatter plot that he/she created from the collected data. (Algorithmic Skill)
- VI. The student will use method of slope of the line to estimate the equations that best describe the collected data and to make predictions. (Algorithmic Skill)

Language Objective(s):

1. The student will explain the difference between positive, negative and zero correlation.
2. The student will define linear and nonlinear relation in his or her own words.
3. The student will explain the process of estimating the equation of best line of fit.

Materials Needed:

- 1 Scatter plot example sheet
- 2 Rulers
- 3 Graph paper
- 4 Homework #6

Sequence of Activities

- ❖ Begin the day's lesson by having students compare their scatter plots in their groups. Since the plots are from the same data and they were expected to use the same plotting criteria, the plots should be the same. Have them discuss differences in the plots and correct their mistakes if any.
- ❖ Have student put away homework #5 and begin to work on worksheet #6 (Scatter plot example sheet). Have students look at the two groups of scatter plot and differentiate

between groups of examples and non-examples of linear relationships. *The goal is for them to be able to classify them as linear and nonlinear with explanations.* Have each group make a conjecture about how the examples are alike and how they differ from the non-examples.

- ❖ Have groups share their conjectures with the whole class, come up with general terms that will introduce the term linear and nonlinear relationship between two variables (bivariates). Lead students to make connections between their own wordings (*possibly 'it is straight' vs. not straight or curves*) and the terms (linear and nonlinear).
- ❖ Lead students to understand what we mean by relationship/association. Let them know these are synonyms of correlation, which is an important concept in statistics. After establishing linearity and nonlinear associations or relationships also known as **correlations** between bivariates, go on to introduce types of linear relationship or correlations. That is positive, negative and zero correlations

Correlation

- ❖ Lead a class discussion on positive, negative and zero correlation and ask students to give examples of variables that would have each type of correlation. Illustrate the relationship with climbing a slant hill.
 - Positive is like climbing up a slide or upward on a slant hill
 - Negative is climbing down the hill or downward on a slant hill
 - Zero is a flat surface, no specific pattern.
 - Refer to the examples on the scatter plot example worksheet.

Best line of fit

- ❖ Fit a line through the scatter plot example sheet to demonstrate how to draw a best line of fit. Let student know that my best line of fit may be different from others' but there is a mathematical best line of fit. A line of best fit should be drawn in a way to summarize the relationship between the variables in the data as presented on scatter plots. The line is also used to predict unknown values in our data set.
- ❖ Best line of fit is the line that best represent the data. It is that line that minimizes error as much as possible. A line of best fit is similar to slope of a line.

- ❖ Explain how to draw a best line of fit using any two data points. Look through the scatter plot and try to draw a line that represents all the data points, the line does not necessarily have to pass through all the data points but must be as close as possible.
 - Use the previous example to demonstrate best line of fit with the class.

Equation of the line of best fit

- ❖ Lead student to discover how to find the equation of the best line of fit. Recall how to find slope of a line given two coordinates points. The equation of a line with slope m and y-intercept b is $y=mx+b$. The equation of best line of fit is the similar, it is usually written as $y= a+ bx$, where, a is y-intercept and b is the correlation coefficient, r .
 - Steps for finding the equation of best line of fit:
 - Identify two points on a line of best fit, say (x_1, y_1) and (x_2, y_2) , then use the formula $m = \frac{\text{change in } y}{\text{change in } x}$, to find b . That is $b = \frac{y_2 - y_1}{x_2 - x_1}$
 - We can also use statistical formula to find 'a' and 'b' which is not required for this unit.
 - $b = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sum(x_i - \bar{x})^2}$
 - a is y-intercept $\bar{y} - b_1\bar{x}$
 - Use the study time and test score example above to demonstrate a line of best fit and equation of the line.
- ❖ Have student bring out their group scatter plots and draw a best line of fit through them.
- ❖ Estimate the equation of their line and use the equation to predict a point which is not on their data set. For example find the time it takes to drain a bucket containing water of height 5.5cm.
- ❖ Review the day's lesson and assign homework #6.

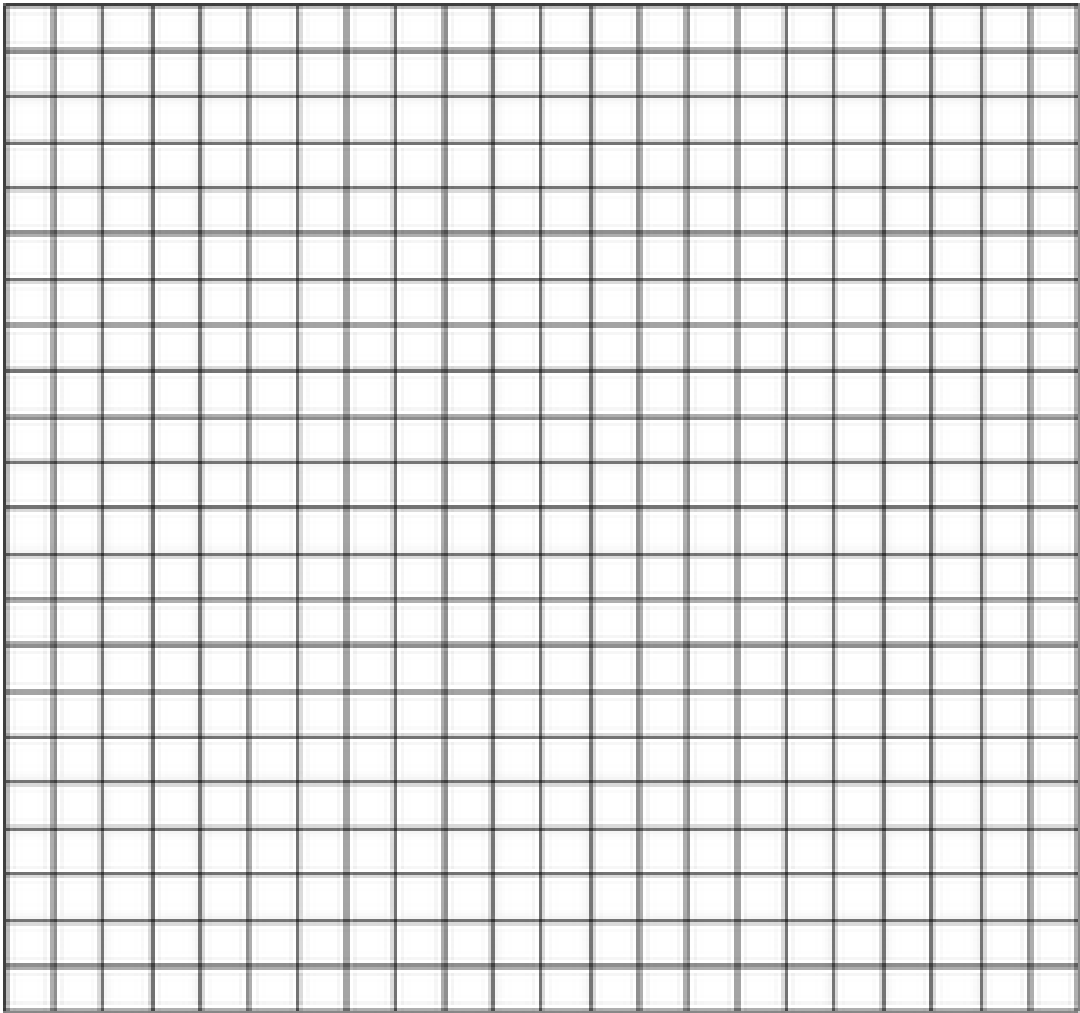
Homework #6_ Scatter Plot, Best Line of fit and Equation

Name: _____ Date: _____

Copied from textbook

Miles Driven	200	322	250	290	310	135	60	150	180	70	315	175
Fuel Used (gallon)	7.5	14	11	10	10	5	2.3	5	6.2	3	11	6.5

- a. Make a scatter plot for this data
- b. Draw a line that best “fits” the data in the scatter plot. Find an equation of the line.
- c. Use the equation to predict the miles driven if 15 gallons of fuel was used.

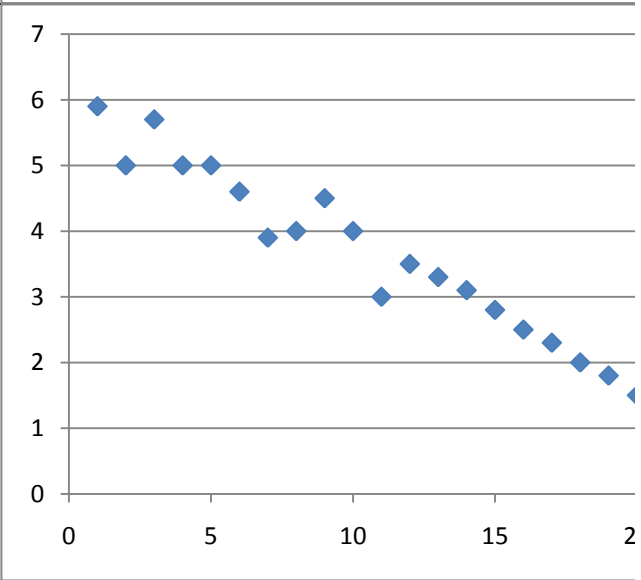
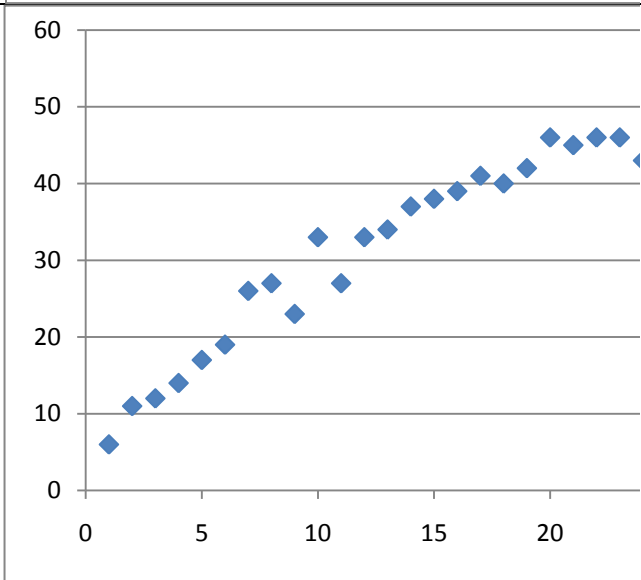
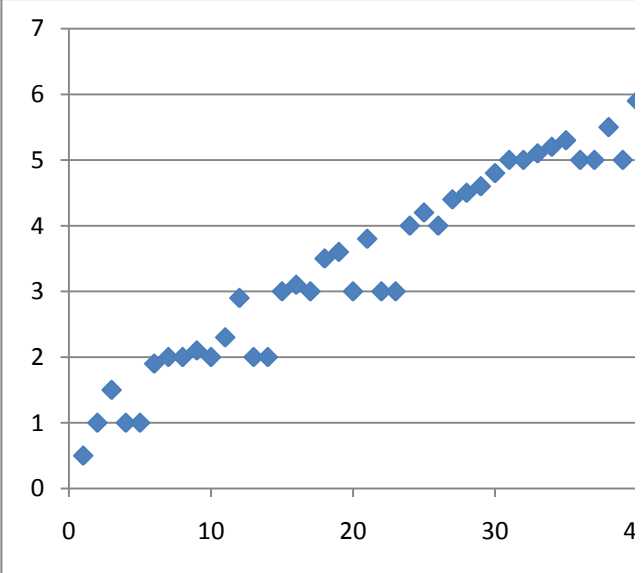
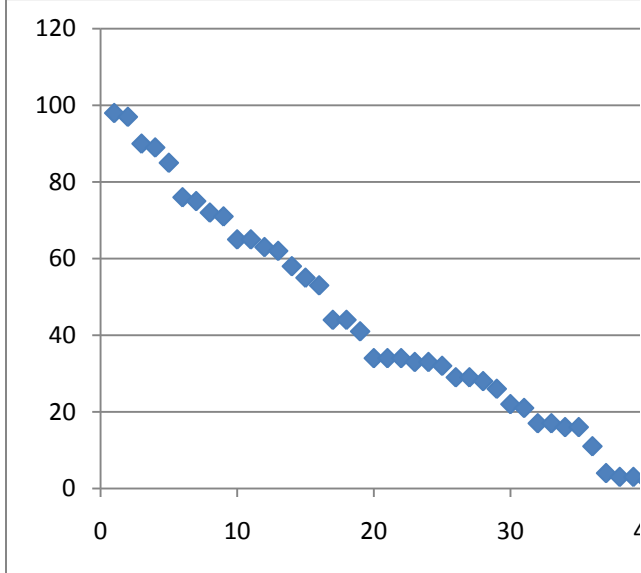


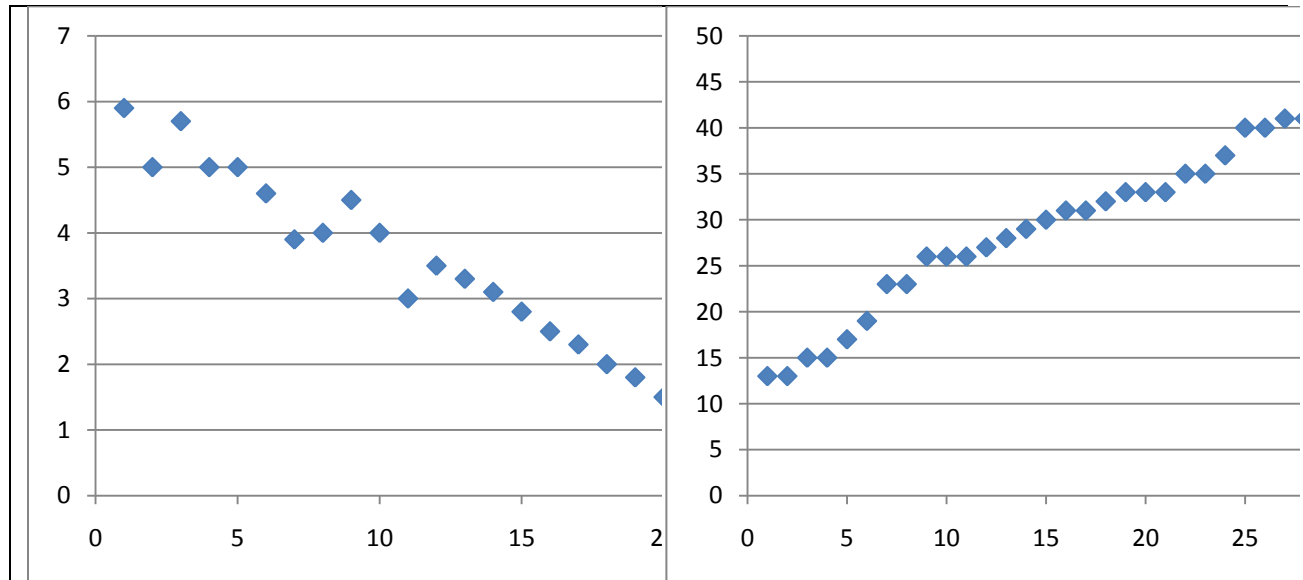
Worksheet #7 _Scatter Plot Example sheet

Name: _____

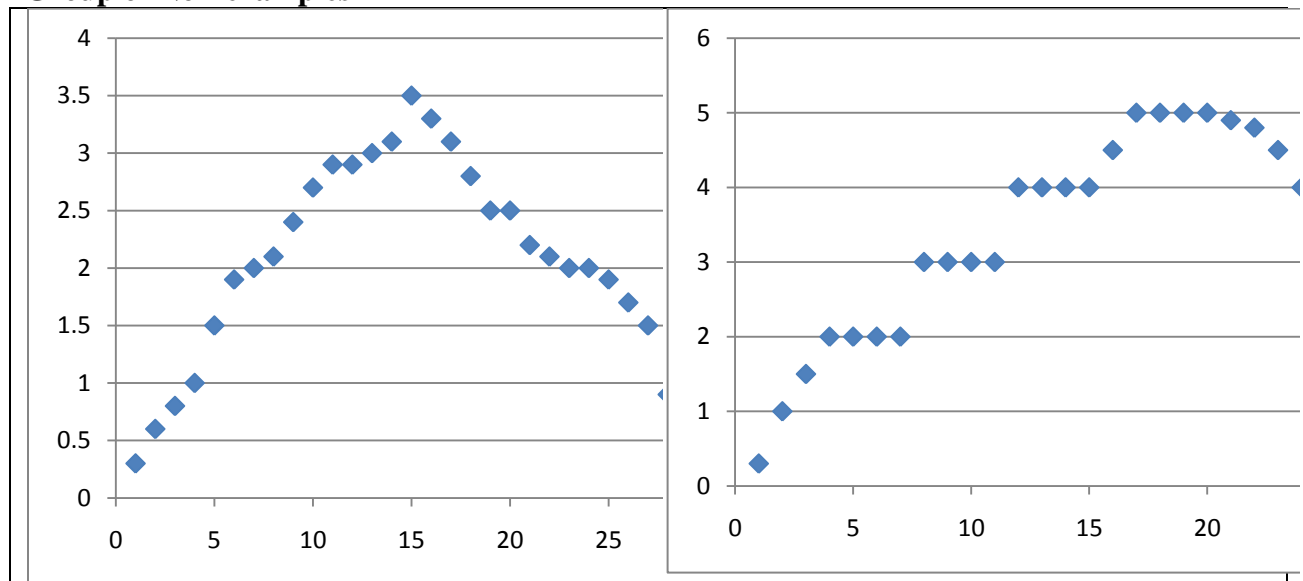
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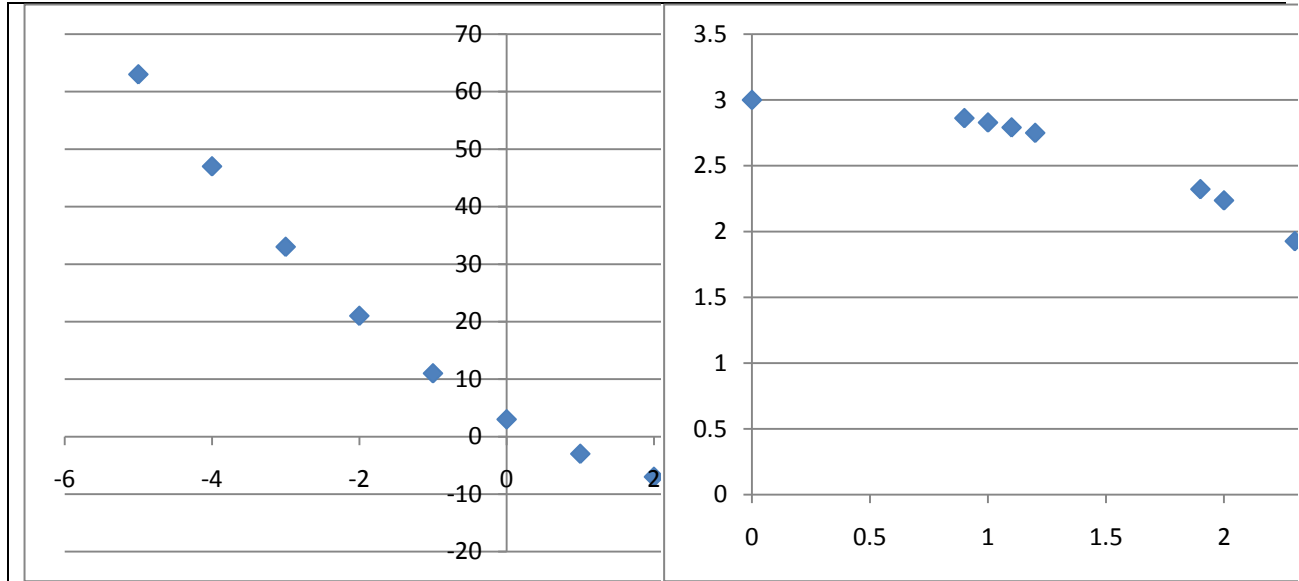
Group of Examples



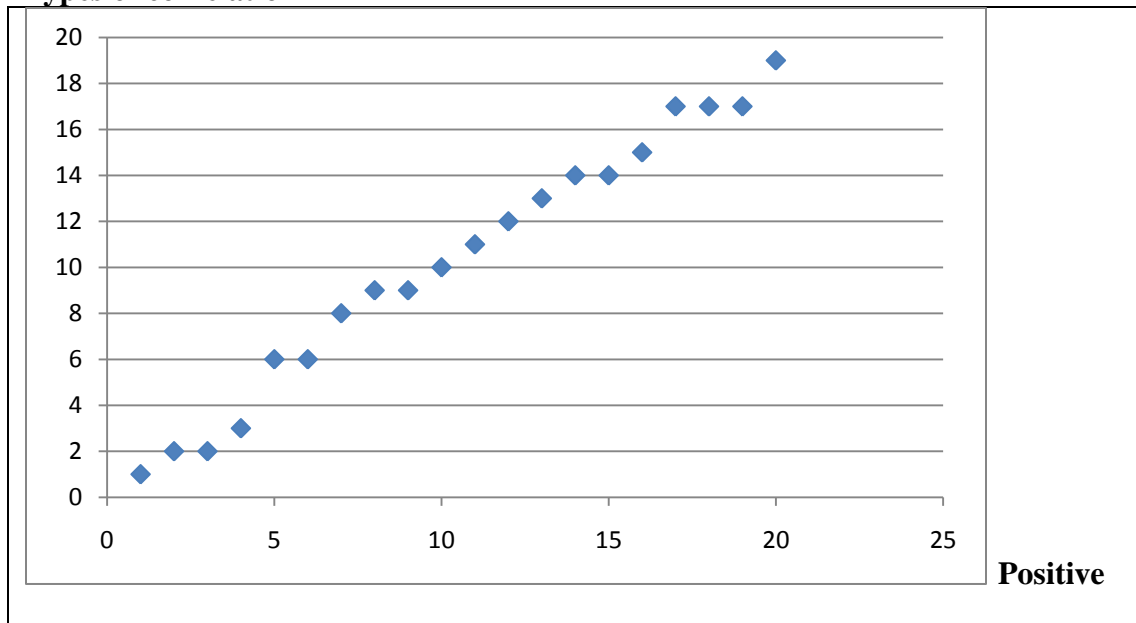


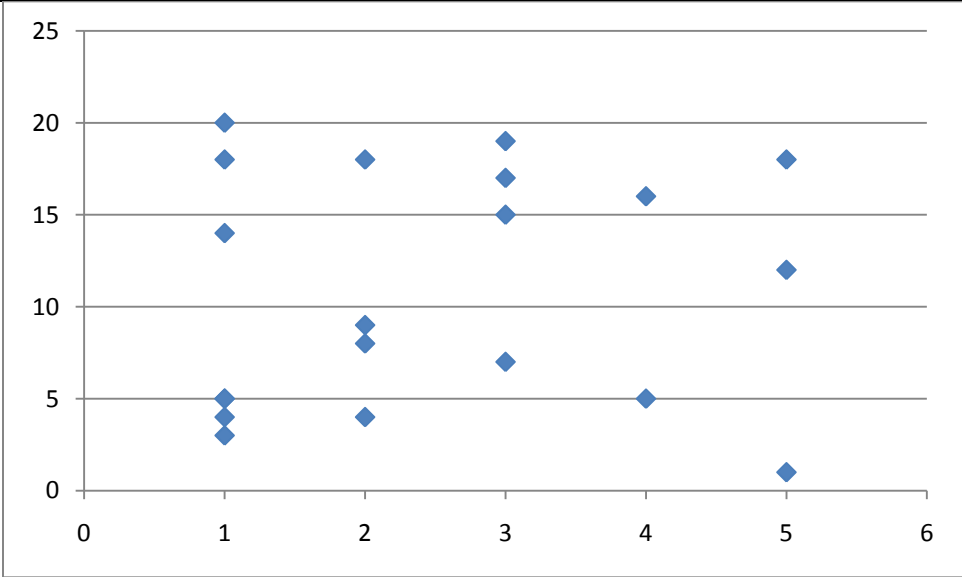
Group of Non-examples



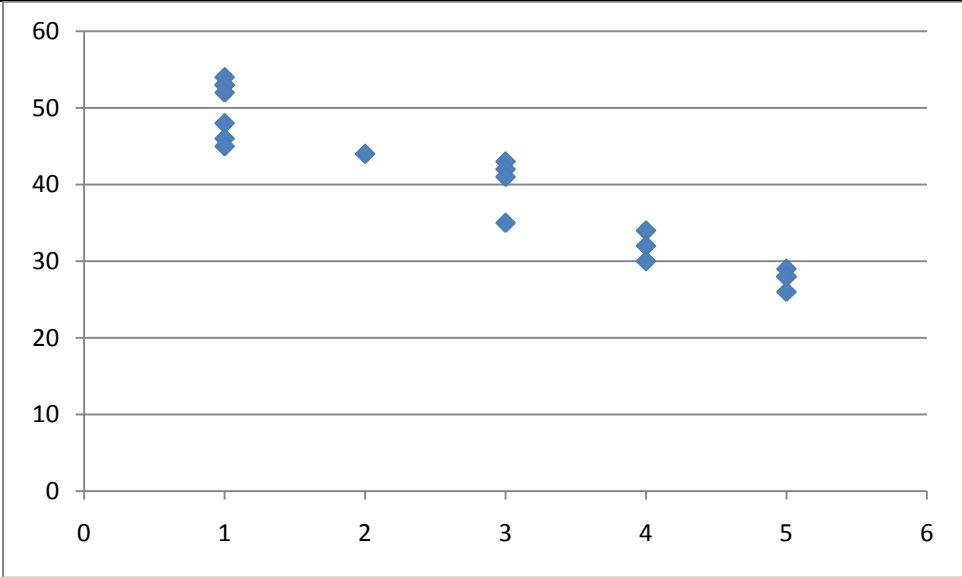


Types of correlation





Zero



Negative

Leaky Bucket Experiment Unit- Day 7

Content Objectives for Day 7:

- I. The student will learn some basic facts about Torricelli Principles. (Simple Knowledge)
- II. The student will learn how to use excel spreadsheet to make scatter plots. (Algorithmic Skills)
- III. The student will be able to use excel spreadsheet to draw best lines of fit and the equation of the line. (Algorithmic Skills)
- IV. The student will interpret the results produced from excel spreadsheet. (Comprehension and Communication)
- V. The student will compare and interpret the result of data collected using equation of best line of fit with Torricelli's equations. (Comprehension and Communication)

Language Objective(s):

1. The student will read and explain what they learned from the reading extract.
2. The student will explain how the process of estimating the equation of best line of fit with excel spreadsheet differ from the manually computed one.

Materials Needed:

1. Reading materials/extract on Torricelli and his mathematical equation.
2. Leaky bucket groups data (collected during the experiment)
3. Computers (if possible one per student)
4. Homework #7

Sequence of Activities

- ❖ Have students discuss homework #6 in their groups. Note that best line of fits and equations may differ but the difference should be small. Clarify misconceptions if there are any.

- ❖ Give out the extract or text about Torricelli and his principles to each student. Give them 10 minutes to read through. Have student discuss what they learned from the reading in their groups. Call on students to share with class.
- ❖ Let students know that Torricelli's equation has worked for many years. So we will like to see how our equations compare to his in predicting time and height of leaky buckets.

Using Excel Spreadsheet to make Scatter Plots and best lines of fit

- ❖ Have student move to the computer lab to demonstrate how to make scatter plots, draw a best line of fit and estimate the equation of the line using excel spread sheet.
- ❖ Put a power point presentation together or a simple direction document, to illustrate a step by step procedure of how to use excel spread sheet. Project the document on overhead projector so that it is visible to all the students.
- ❖ Have students demonstrate using excel to analyze their individual group data collected during the experiment. Have them make scatter plot and interpret their results.
- ❖ Have students compare their excel spread sheet result with the manually computed representations.
- ❖ Explain the difference between a best line of fit and the best line of fit.
- ❖ Summarize the learning activities for the day and assign homework #7

Homework #7_ Leaky Bucket

What are the similarities between your Leaky Bucket prediction equation and Torricelli's? What are the differences you noticed?

Do you like working with excel spread sheet? If yes explain why, if not explain?

What is it you like the most in the Leaky Bucket experiment unit?

What is it that you learned from the unit?

What do you wish we could have done differently? Is there something you did not like about the unit? Yes/No. Suggest ways we can improve on the unit?

<http://www.nndb.com/people/605/000087344/>
<http://brunelleschi.imss.fi.it/museum/esim.asp?c=300562>

Evangelista Torricelli

1608-1647

Born: 15-Oct-1608

Birthplace: Faenza, Romagna, Italy

Died: 25-Oct-1647

Location of death: Florence, Italy

Cause of death: Typhus

Gender: Male

Race or Ethnicity: White

Occupation: Mathematician, Scientist

Nationality: Italy

Executive summary: Inventor of the barometer

Italian physicist and mathematician, born at Faenza on the 15th of October 1608. Left fatherless at an early age, he was educated under the care of his uncle, a Camaldolese monk, who in 1627 sent him to Rome to study science under the Benedictine Benedetto Castelli (1577-1644), professor of mathematics at the Collegio di Sapienza.



After two years of study "under the discipline of the Jesuit Fathers," Torricelli became a pupil of Benedetto Castelli (1578-1643) at eighteen. Not much is known of the young Torricelli's life between 1632 and 1641. He joined the staff of Giovanni Ciampoli (1589-1643), a friend and admirer of Galileo (1564-1642), sent to the Marche as Governor. During this period, Torricelli conducted a thorough study of Galileo's theory of motion. He returned to Rome in early 1641 but left for Florence in early October to assist Galileo in the last months of his life. After Galileo's death, Ferdinand II de' Medici (1610-1670) appointed Torricelli Granducal Mathematician and lecturer in mathematics at the University of Pisa. In Florence, he undertook research in geometry. In particular, he perfected Bonaventura Cavalieri's (1598-1647) method of indivisibles, for example by introducing curved indivisibles. In 1644, Torricelli published *Opera Geometrica*. In the same year, he performed the celebrated experiment demonstrating the effects of atmospheric pressure. He also developed a consummate skill in grinding telescope lenses. His lenses were of excellent quality and avidly sought after. Struck by a grave illness while still young, he died in Florence in the night of October 24-25, 1647. After his death, a painstaking but fruitless search was carried out to discover the "secret of the spectacles," i.e., Torricelli's methods for producing lenses of unmatched perfection.

<http://www.britannica.com/EBchecked/topic/600154/Torricellis-theorem>

Encyclopedia Britannica

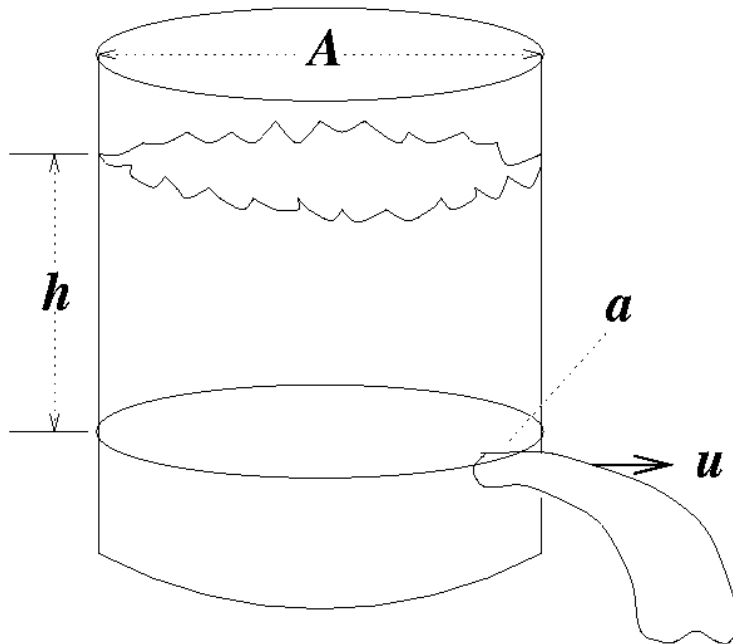
Torricelli theorem

*also called **Torricelli's law**, **Torricelli's principle**, or **Torricelli's equation***

statement that the speed, v , of a [liquid](#) flowing under the force of gravity out of an opening in a tank is proportional jointly to the [square root](#) of the vertical distance, h , between the liquid surface and the centre of the opening and to the square root of twice the acceleration caused by gravity, $2g$, or simply $v = (2gh)^{1/2}$. (The value of the acceleration caused by gravity at the Earth's surface is about 32.2 feet per second per second, or 9.8 metres per second per second.) The theorem is named after [Evangelista Torricelli](#), who discovered it in 1643.

The speed of a portion of water flowing through an opening in a tank a given distance, h , below the water surface is the same as the speed that would be attained by a drop of water falling freely under the force of gravity alone (that is, neglecting effects of air) through the same distance, h . The speed of efflux is independent of the direction of flow; at the point of the opening the speed is given by this equation, whether the opening is directed upward, downward, or horizontally.

Derivation



By Dr Jim Powell

Figure 1 Leaky bucket showing cross-sectional area, A , height of fluid in the bucket, h , area of hole, a , and u represents flow rate.

Mathematicians and scientists solved Torricelli's equation, $v = \sqrt{2gh}$, using method of differentiation. They came up with a solution for finding the time it takes to completely empty a container as in leaky bucket. The formula is $t_{empty} = \frac{2A\sqrt{h_0}}{a\sqrt{2g}}$ and the formula for finding height at

a particular time t is given as $h = \left(\sqrt{h_0} - \frac{a\sqrt{2g}}{2A}t \right)^2$.

Lesson Plan- Leaky Bucket Experiment Unit- Day 8

Content Objectives for Day 8:

- VI. The student will write detailed report on leaky bucket experiment.
(Comprehension and Communication)
- VII. The student will read and make suggestions on how to improve one another's write up. (Comprehension and Communication)

Language Objective(s):

- 1. The students will write a summary report of all they have learned from the leaky bucket unit.

Materials Needed:

- 1. Guided notes for report writing.
- 2. Written report to be submitted at the end of the unit.

Sequence of Activities

- ❖ Have students share some of their responses to homework #7. Recall the overall learning goal and talk about how much of the objectives were achieved.
- ❖ Hand student the guided notes or summary outline and have student work independently on the summary. Allow group members to have discussions that can help them with the write-up.
- ❖ Allow student time to read their write-up to a partner. If need be give them time to modify their report before submitting.
- ❖ Collect reports at the end of class to be graded.

Worksheet #8 Leaky Bucket project report

- Describe the Leaky Bucket experiment.
- What are the variables you worked with in the experiment? How would classify your variable(s)?
- Which variable did you hold constant and which did you work with and why?
- How would you apply the knowledge gained from the Leaky Bucket experiment unit in real-life situation?
- Did creating a scatter plot help you to learn anything about the data you collected in your group? Why or why not?

- On Day 5, you collected some data, was your data collection perfect? Why or why not?
- What are some of the reasons for imperfections of your data collection? How can you correct such in the future?
- How was your result similar to the mathematician's (Torricelli) equation and how are they different?
- How did your knowledge of variables helped with data collection, analysis and interpretation of results?
- Was your knowledge of slope helpful with data collection, analysis and interpretation of results? Explain how.

- Based on the results obtained from the collection, analyzing and interpretations of data, do you think Torricelli's equation is a good predictor of emptying time of Leaky Buckets? Explain.
- Write about your learning experience with Leaky Bucket experiment unit.

5.0 Conclusion

For more than four decades, mathematics educators have been calling for reforms that will lead to better teaching and learning of mathematics. The purpose of mathematics education reform is to move instruction away from the passive transmission model, of rote memorization featuring one blackboard, one outspoken teacher, and group passive students to a constructivist model, where the learner actively participates with other students and the teacher in inquiry, problem solving, and knowledge construction (Draper, 2002; Giroux, 2004; Ladson-Billings, 1995; Mistrestta, 2005). However, higher order thinking skills rarely dominate mathematics educators' teaching strategies (Stigler and Hiebert, 1999), creating lack of appreciation and low performances in mathematics.

In this study, the author proposed a project-based learning unit that will lead students to collect, record, analyze, display and interpret real data using scatter plots and mathematical equations. Researchers have shown that project-based unit (Frykholm & Glasson, 2005; Herron-Thorpe, et al., 2010Morrison et al., 2009; Wilhelm et al., 2008) like the one proposed has the ability to deepen students' contextual understanding of topics as well as develop their appreciations for making interdisciplinary connections.

For further study, the unit will be tried with real student in a real world learning environment.

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APPENDIX

I. Sample Solution of Assessments**A. Worksheet #2_Survey**

Name: Florence Obielodan Date: 01/17/2011 Group Name: Alpha

Group Members: Jane, James, John, Jon, Jess

Q1 Answer:

9. Jan_, Nov_, Mar_, _May, and Mar_
10. 13_, 12_, 13_, 14_, and 14_
11. 45_, 43_, 57_, 41_, and 48__
12. 3, 5, 6, 4, and 4
13. Blue, purple, green, white and yellow
14. 38, 39, 37, 38, and 37
15. blue, blue, brown, blue, and brown
16. English, English, Geometry, English, and Science

Q2. Re-write the information collected in Q1 in the table below

	Member1	Member2	Member3	Member4	Member5
Month of your birth	Jan	Nov	Mar	May	Mar
Age	13	12	13	14	14
Height in inches	45	43	57	41	48
Number of people in family	3	5	6	4	4
Favorite color	Blue	Purple	Green	White	yellow
Shoe size	38	39	37	38	37
Eye color	Blue	Blue	Brown	Blue	brown
Favorite subject	English	English	Geometry	English	Science

Q3. In what ways is the presentation of the responses to Q1 different from that of Q2? How are they related? Explain.

The information in Q1 is the same as in Q2. It is different, because each member's answers to the questions are clearly written out in a table. This makes it easier to know everything about each member.

Q4. Which of the two forms of response presentations do you like the most and why?

The table forms in Q2, because it is easier to read and understand each member's answers to all the questions.

B. Worksheet #3_ Data representations

Name: _____Sammy_____ Date: _____01/21/2011_____

Direction: Read the information below and answer the questions that follow

Mrs. Cannon wants to study the distribution of the scores for a 100-point unit exam given in her first-hour mathematics class. The scores of the 25 students in the class are listed below.

82 77 49 84 44

98 93 71 76 65

89 95 78 69 89

64 88 54 96 87

93 80 89 85 93

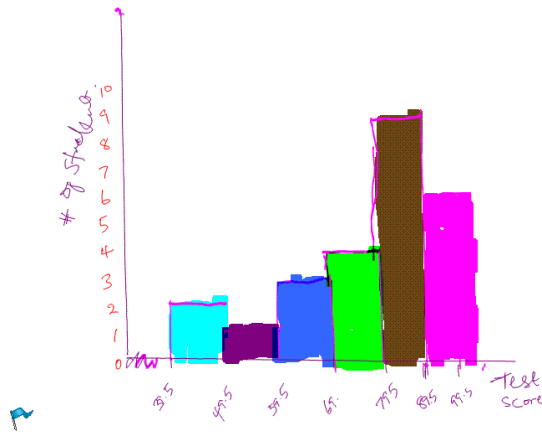
- a. Make a stem-and-leaf plot for the mathematics exam scores. [you can find steam-and-leaf on page -- of your mathematics textbook]

Stem	Leaf
4	4 9
5	4
6	4 5 9
7	1 6 7 8
8	0 2 4 5 7 8 9 9 9
9	2 3 3 5 6 8

- b. Represent the information on a frequency table with the intervals 40-49, 50-59, 60-69, etc (You can find frequency table on page -- of your mathematics textbook)

Test interval	Number of student	
	Tally	Frequency
40-49	II	2
50-59	I	1
60-69	III	3
70-79	IIII	4
80-89	HHI IIII	9
90-99	IHI I	6

- b. Construct a histogram for the exam scores. [you can find histogram on page -- of your mathematics textbook]



- c. What is the highest score on the exam? _____98_____
- d. What is the lowest score? _____44_____
- e. Which test score appear most frequently? _____89_____

C. Mini- experiment #1

Name: _____Max_____ Date: _____01/01/01_____ Class: _____1st hour_____

Prompt

List and explain three techniques or methods of collecting data.

Response:

- 1.-----Survey-----
- 2.-----Observation-----
- 3.-----Field work-----

D. Worksheet #4_Variable Example SheetName: _____ **Suzy** _____ Date _____ **01/11/2011** _____**Part 1****Examples: variables***(Students' worksheet will exclude the title variables just group of examples and non-examples)*

- ✚ The level of noise in a class when the teacher leaves the room.
- ✚ Length of time taken to study in preparation for end of unit test.
- ✚ Favorite class of music of teenagers or their parents.
- ✚ The speed at which a candle stick burns
- ✚ Number of vehicles arriving at a bus stop daily.
- ✚ Effect of fertilizer on plants
- ✚ The value of X, when X is greater or equal to 5
- ✚ The value of $X + Y$
- ✚ The value of $X + 2$

Non Example: Not Variables

- The number of vehicles that arrive at a bus stop at exactly 2:30pm on Monday July 19, 2010 afternoon.
- The value of Y, when $X + Y = 25$; given that $X = 10$ (Note: X and Y are positive integers)
- $X + 2 = 5$, if X is an integer, its value is
- The student who sits directly behind Jon Jones in our Science class.

Question

Examine the group of examples and non-examples and write three things that make the group of examples different from the non-example group.

Response

4. -Values of examples can change from time to time -----
5. -----non examples are fixed-----
6. ----The group of non examples is always the same number , position or symbol, while,
the group of examples can assume any number, condition, character or symbol-----

Part 2

Direction:

A Identify which data set or statements are univariate and which are bivariate and name the variable in the statement.

1. The number of goals scored by the school basketball team
2. The number of people in a household and their family income.
3. The sizes of sneakers and their prices.
4. The amount of gas in a car and miles travelled.
5. Number of hours spent studying for geography and science test.
6. The month you were born and the first letter of your name.
7. Effect of fertilizer on plants.
8. Favorite music of teenagers and their parents.

Univariate	The variable	Bivariate	The variables
#1	goals	#2	# of people & income
#5	Study hours	#3	Sizes & prices
#7	Fertilizer's effect	#4	Amount of gas & miles travelled
#8	Favorite music	#6	Month of birth & first letter of name

B Classify the following as dependent and independent variable.

1. The number of hours spent studying for a test and the test score.
2. The age and the height of babies.
3. The level noise in the classroom and teacher's presence.
4. Time spent in the mall and dollars spent in the mall.
5. Distance travelled by a car and the amount of gas in the car.

Statement #	Independent	Dependent
1	Study time	Test score
2	age	height
3	Teacher's presence	Noise level
4	Time in the mall	Dollars spent
5	Amount of gas	Distance travelled

E. Homework #3_ Volume problem

Name: _____Faith_____ Date: _____10/10/10_____

Direction: Explain the process that you will use to solve the following problem (You do not need to solve the problem just explain the steps involved).

Question: Suppose the diameter of a Soda can is d cm and a height of h cm, find the volume of the Soda in the Can if 0.5 cm of space is left at the top of the can to allow for expansion?

1. What information gives you the clue on how to solve the problem?
____Find the volume of Can of soda; what shape is the can? Cylinder____
2. Identify the key variables and their values in the problem. _____diameter, height, and volume_____
3. Write an equation to show how you would solve it?

$$V = \pi \left(\frac{d}{2}\right)^2 h$$

F. Mini- experiment #2Name: _____Faithful_____ Date: _____01/10/11_____ Class: _____1st hour_____**Prompt**

1. Variables are _____changing/varying_____ quantities, and not _____fixed or constant_____
2. The statement “The ages and the first letter of students’ names” is an example of _____bivariate_____ type of variable.
3. How is dependent variable different from independent variable? ____

Independent variables: The variables that researcher can change (have control on) in experiments, whose values determine what the value of the dependent variable should be. While dependent variables are directly dependent upon the values of other variables in a mathematical relationship_____

4. Identify two characteristics of variables
 - (i) It changes or varies
 - (ii) It is measureable

G. Homework #4_ Cartesian coordinates and Slope Review

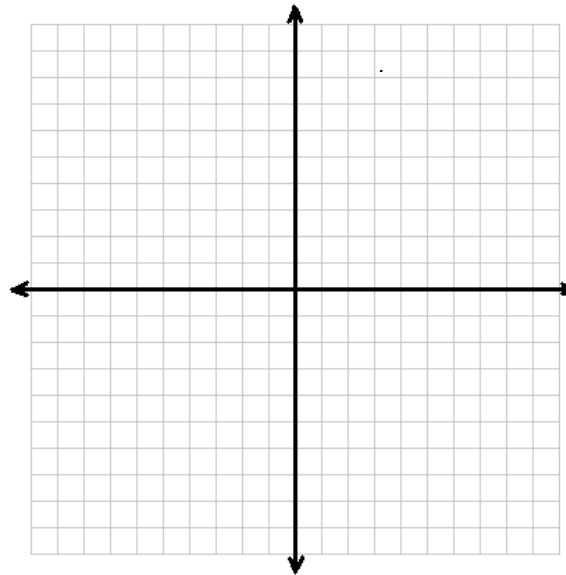
Name: _____Faithfulness_____ Date: _____10/10/10_____

Remember all points are named as (x, y) and called ordered pairs. The x-axis is the horizontal axis (the run) and the y-axis is the vertical axis (the rise).

1. Doris sits on a seat which is on the third row and on the fourth column, while Greg's seat is on the fourth row but third column. Are both students sharing the same seat? Yes/**No**. Explain the reason for your answer, use diagram if possible.

R1/C1	C2	C3	C4	C5
R2				
R3			Doris	
R4		Greg		
R5				

2. Plot and label the points A (-5, 5); B (-8,-3); C (5, -3) and D (8, 5) on the graph below. Join your points using straight lines, what shape have you drawn?



3. Recall that the slope of a line is defined as rise over run or change in y over change in x. write a formula for finding the slope of the line containing the points (x₁,y₁) and (x₂,y₂).

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

4. The line with the equation $y = mx + b$ is a straight line with slope m and y-intercept b .

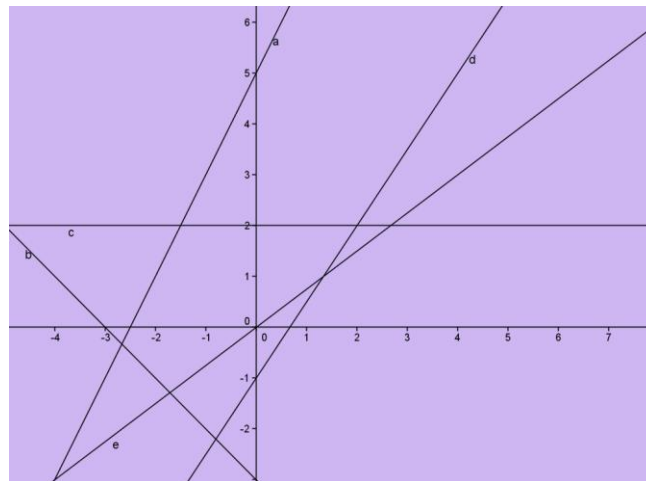
5. Find the slope of the line containing the points $(-2, -3)$ and $(5, -3)$

$$m = \frac{-3 - (-3)}{5 - (-2)} = \frac{-3 + 3}{5 + 2} = \frac{0}{7} = 0$$

6. Find the slope of the line that passes through the points $(0, 0)$ and $(4, 3)$

$$m = \frac{4 - 0}{3 - 0} = \frac{4}{3}$$

7. Classify the following lines as having positive, negative, zero or undefined slope. Write your answer on the line below the graph.



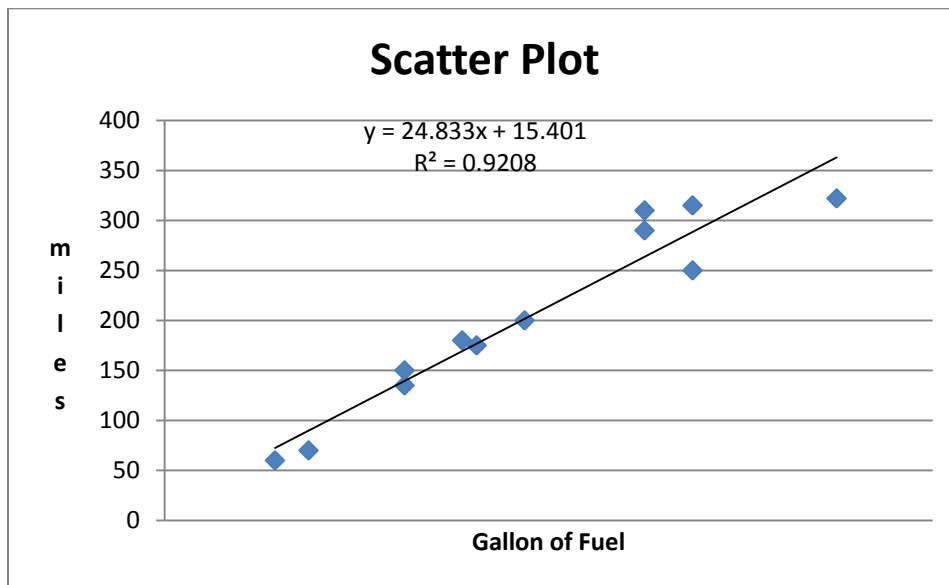
- a. -----positive-----
 b. -----negative-----
 c. -----zero-----
 d. -----positive-----
 e. -----positive-----

H. Homework #6_ Scatter Plot, Best Line of fit and EquationName: FlorenceDate: 02/02/2011

Copied from online textbook

Miles Driven	200	322	250	290	310	135	60	150	180	70	315	175
Fuel Used (gallon)	7.5	14	11	10	10	5	2.3	5	6.2	3	11	6.5

- Make a scatter plot for this data
- Draw a line that best “fits” the data in the scatter plot. Find an equation of the line.
- Use the equation to predict the miles driven if 15 gallons of fuel was used.




Miles travelled if 15 gallon of fuel was used is $24.833(15) + 15.401 = 387.896$


Note

Make manually computed scatter plot and compare with the excel spreadsheet results

II. Power point slides




Methods of Data collection




Purpose of collecting data

- For research purpose
- For decision making
- For future predictions
- to confirm old finding and make new conclusion about some ideas




Some methods

- Survey
 - Interview
 - Questionnaire
- Observation
- Field work
- Experimentation




Interview

- Face-to face talk
 - Parties to interview are
 - Interviewer
 - Interviewee
 - advantages
- Reliable
 - quick and immediate response
 - Allow for a friendly relationship with interviewee
 - Ambiguous questions can be clarified for better response.
 - Disadvantages
 - Not practical for large sample
 - Time and money consuming
 - Another approach is telephone interview




Questionnaire

- Paper and pencil response
- Can be use for large number of people (respondents)
 - advantages
- Save the researcher time and money
- Some honest responses because the interviewer is not present in person
 - disadvantage
- Many may not respond or refuse to return questionnaire.
- [Sample of Questionnaire.docx](#)




Experiment

- Conduct experiment in a laboratory
- Involves observation
- Recording findings or results
- Used results for decision making and future prediction
- Cost and time consuming
- Procedures can be tedious



Field work

- Teachers and student in a classroom
- Engineers working at a site
- Scientists collecting data in a lab
- A farmer on his farm



Observation

- All methods of collecting data involve making observations
- Observation is to look critically or examine with care to note tiny little details that are important in a research

III.**Sample of Questionnaire**

Survey Questions on School Lunches

Please circle the option that best describe your response to the following questions:

1. Male Female
2. Grades: k 1 2 3 4 5 6 7 8

On a scale of 1 to 5, 1 meaning excellent, 2 is very good, 3 is fair, 4 represents poor and 5 very poor.

3. How will you rate school lunches? 1 2 3 4 5
4. How will you rate your lunch room and environment? 1 2 3 4 5
5. Which is your favorite school lunch? _____ Why is it your best? _____
6. If you have opportunity to change a meal, which meal will you have changed and why?

7. Which meal would you like to be included in your lunch schedule? _____
and on what day of the week would you like that serve? _____